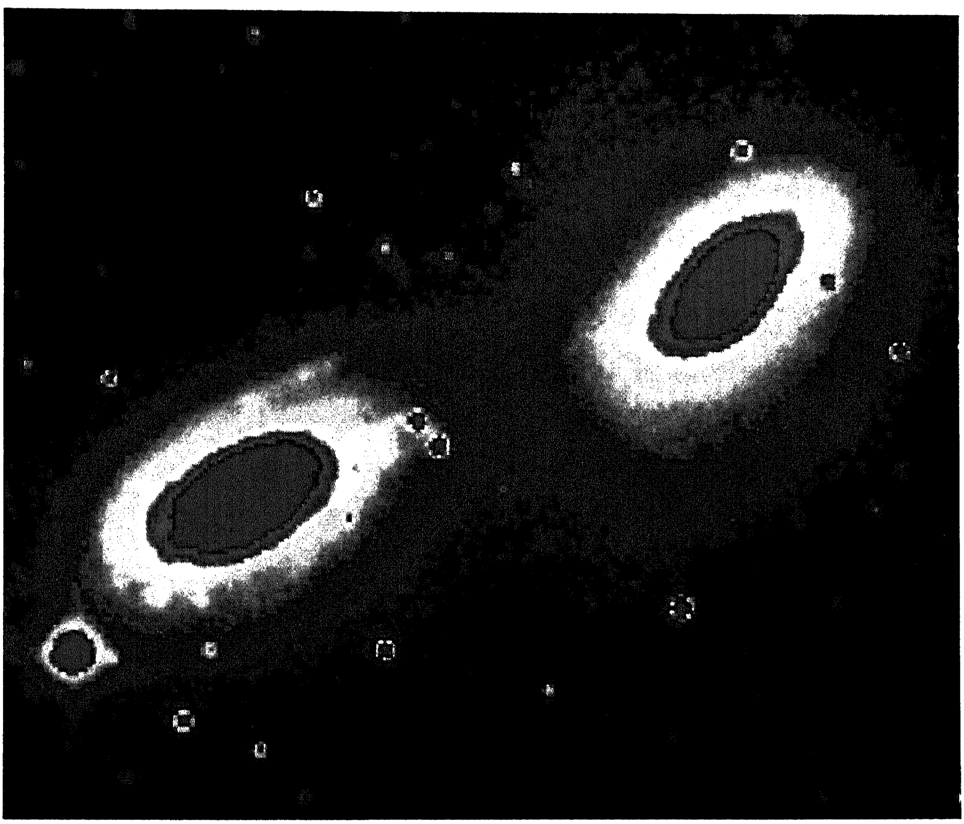
# Resonance

January 1996 Volume 1 Number 1

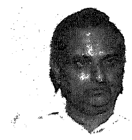
journal of science education

Origin (?) of the Universe ◆ The Honeybee Dance-Language Controversy ◆ Fermat's Last Theorem ◆ Learning Organic Chemistry Through Natural Products ◆ Know Your Personal Computer

# A New Venture

*P Rama Rao, President, Indian Academy of Sciences*



You now hold in your hands the fruits of over a year's intensive effort by the Indian Academy of Sciences. In recent years the Academy been increasingly concerned about the state of science education in the country. A panel was therefore constituted by Prof R Narasimha, the then President of the Academy, in July 1994 to advise the Academy, and other organisations in the country, on what they can do to help in this matter. One of the major recommendations of that panel was that the Academy launch a journal of science education, primarily targeted at undergraduate students and teachers. Accepting this recommendation, the Indian Academy of Sciences has now commenced publication of ***Resonance - journal of science education.***

As you will see in this and future issues, ***Resonance*** will focus, among other things, on such topics in the science curriculum, that by common experience, are difficult to teach and grasp. ***Resonance*** is designed to serve the long felt need for a medium of communication among students, teachers and practising scientists and will thus enrich the processes of teaching and learning science. Such an effort can only be successfully sustained with the participation and cooperation of a large number of Fellows of the Academy, other scientists, teachers and students. Judging by the number of individuals who have already contributed to the launching of ***Resonance***, I feel that the required participation and cooperation will be seen in abundant measure.

**_Resonance_ will focus on such topics in the science curriculum that by common experience, are difficult to teach and grasp.**

Prof N Mukunda and his large band of Editors, Corresponding Editors, authors and referees have worked hard to launch ***Resonance*** through this inaugural issue. I wish them continued success in this endeavour, and express the hope that ***Resonance*** will stimulate science education in the country.

**Resonance** journal of science education

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## SERIES ARTICLES

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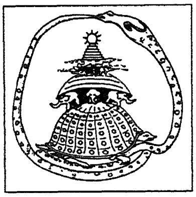

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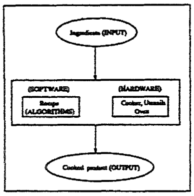

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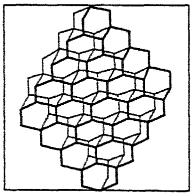



## GENERAL ARTICLES

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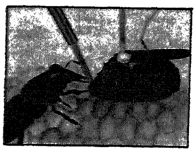
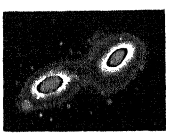
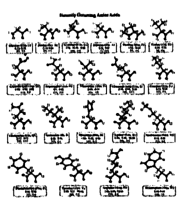




**Front Cover**
The world beyond our Milky Way galaxy contains several exciting objects. Shown here are two galaxies IC 2200 - IC 2200 A which form a binary system in gravitational interaction. *(Observed at the Las Campanas Observatory, Chile on 29 January 1995; processed at IUCAA.)*

**Back Cover**
Pierre-Simon de Fermat (1601-1665).



**Poster**
Naturally Occurring Amino Acids.

# Editorial

*N Mukunda, Chief Editor*

**There is an encouraging trend of good quality popularization of science; journals of education already exist in specific areas, and active and effective peoples' science movements have emerged. We see our effort as complementing all of these, yet possessing distinctive features of its own.**

It is with feelings of pleasure, anticipation and hope that we present this inaugural issue of ***Resonance*** to our readers. This journal is being launched by the Indian Academy of Sciences as part of its initiative to contribute constructively to science education in our colleges and universities. We hope through ***Resonance*** to reach teachers and students of science all over the country, and in turn appreciate better their interests and needs.

The main target audience we have in mind are under-graduate students and teachers of science. However, we do intend to include material of interest to students preparing to enter college, as well as to post graduate and research students. There is an encouraging trend of good quality popularization of science; journals of education already exist in specific areas, and active and effective peoples' science movements have emerged. We see our effort as complementing all of these, yet possessing distinctive features of its own. While we address ourselves largely to those young people who have a genuine interest in understanding and pursuing science, we hope that others too will find ***Resonance*** inviting.

Several months of planning lie behind what you now see before you. Purely for this initial phase of detailed preparatory work, the members of the core editorial group have been drawn from institutions in Bangalore. We are in touch with a larger group of corresponding editors in different fields, from all over the country, and whose names and affiliations appear elsewhere in this

issue. As this inaugural offering exemplifies, we hope to maintain balanced coverage of different areas through a variety of contributions and features: general articles, series devoted to different aspects of a chosen subject, guest columns, question and answer and "classroom" pages for teachers and students alike, book reviews, research and career news, correspondence, to name a few. A conscious effort has been made to work with teachers and students in determining the contents and writing style of ***Resonance***, and this will expand and continue.

We welcome contributions, comments, suggestions and criticism from our readers. Our constant endeavour will be to enhance the attractiveness and accessibility of material to our readers, keeping their needs in view. We hope to convey an understanding of concepts, connections between different fields, the experimental method and the art of rational thinking. We shall also attempt to bring out an appreciation of science as a human activity, its relationship to society, and as an important component of culture in today's world. Not least we wish to make ***Resonance*** visually pleasing.

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Many persons — too numerous to mention — have given us academic and moral support: the President and Fellows of the Academy, and a very large number of teachers, scientists and students in institutions all over the country. We thank them all and express the hope that they and our readers will continually keep in touch with us and support this effort.

## Resonance - Origins and Usage

*The word 'resonance' has acquired various shades of meaning as a result of usage in different contexts.*

*Resonance* is an evocative word which is used in several branches of science. The word entered the English language in the 15th century as an acoustic term to describe the reinforcement or prolongation of sound. A passage in a book from 1491 reads:

> *"Marueyllous howlynges and waylyngs ... whereof the resonnaunce or sonne was soo horryble that it semyd it wente vppe to heuen"*

More commonly, the word is associated with music (resonance of a piano or organ) and in a figurative sense with positive qualities. These are evident in the following powerful phrases: *"For the beaute, for the force and for the resonaunce"* (Ordinary Crysten Men, 1502) and in the pious wish: *"So ought our hearts ... to have no other resonance but of good thoughts"* (World of Wonders, 1607).

The meaning of a word changes with the context. Not surprisingly, a word can acquire new shades of meaning when used in different scientific disciplines. The original term 'resonance' refers to the reinforcing effect caused by reflections or more specifically by synchronous vibrations. However, this phenomenon is not restricted to sound waves, since it may be associated with all periodic processes. As is widely known, troops crossing a bridge are asked to break step; any resonance of synchronous marching with the natural vibrations of the bridge can have disastrous consequences. The same term, resonance, is used to describe the condition of an electrical circuit adjusted to allow the greatest flow of current at a certain frequency. Similarly, a radio set must be in resonance to receive music from a radio station.

High energy physicists encounter very short-lived 'particles', which can be thought of as temporary associations of the components which collide to produce them, or even just as a cluster of states of the system bunched near a given energy. Guess what these entities are called? 'Resonances'! The name is not arbitrary; the graph showing how the probability of collision varies with energy is peaked like resonance. In the same spirit, metastable radical anions of a molecule can be associated with a resonant state in which the neutral molecule has momentarily captured an electron with appropriate energy.

In a general sense, systems with nearly the same energy are said to be in resonance when they are coupled. The phenomenon has important consequences in physics and chemistry. Magnetic resonance, Fermi resonance in infrared spectroscopy, Resonance Raman spectroscopy are all famous examples involving different types of oscillators.

Resonance is also a simple bonding concept in chemistry. Many aspects of structures, stabilities, and charge distributions, especially of conjugated organic molecules, can be readily understood by visualising the total electronic structure as a superposition of building blocks of covalent bonds which are in resonance. While alternative bonding models are available, resonance remains the first choice for a large number of chemists. (A detailed article on the concept of resonance in chemistry will appear in a future issue.)

*J Chandrasekhar*

# Origin (?) of the Universe

## 1. Historical Background

*Jayant V Narlikar*

**The first part of this series covers the historical background to the subject of cosmology — the study of the structure and evolution of the whole universe. Ancient ideas, such as those of the Greeks, already show the beginnings of attempts to account for observations by natural laws, and to prove or disprove these by other observations. It needed the invention of the telescope and studies by scientists like Herschel and Hubble to reach the current understanding of our place in our galaxy, and its place as only one member of a far larger collection of galaxies which fill the observable universe.**

**Jayant Narlikar, Director, Inter-University Centre for Astronomy and Astrophysics, works on action at a distance in physics, new theories of gravitation and new models of the universe. He has made strong efforts to promote teaching and research in astronomy in the universities and also writes extensively in English and Marathi for a wider audience on science and other topics.**

### Primitive Notions of the Universe

An assessment of our present understanding of the cosmos is best carried out with a historical perspective. The written history available today covers a very tiny fraction of the time span of human existence on earth and an even smaller fraction of the age of our planet estimated at some 4.6 billion years. Based even on such limited documentation we find that our ancient forefathers were indeed as curious about nature and the cosmos as we are today.

This six-part series will cover: 1. Historical Background. 2. The Expanding Universe. 3. The Big Bang. 4. The First Three Minutes. 5. Observational Cosmology and 6. Present Challenges in Cosmology.

It is against this background that we should view the attempts our ancient forefathers made to understand the universe around them. They added conjectures and speculations to what they could observe directly. They used fertile imagination to extrapolate from the known to the unknown. Naturally the differing cultural traditions led to different cosmic perspectives in different parts of the world.

I am always impressed by the depth of ideas in our Vedas and Upanishads. Those who wrote them had a questioning mind.

**Our ancient forefathers were indeed as curious about nature and the cosmos as we are today. I am always impressed by the depth of ideas in our Vedas and Upanishads. Those who wrote them had a questioning mind.**

They perceived the complexity of the cosmological problem. The following lines from the Nasadiya Sukta are quite eloquent:

*"Then (in the beginning) there was neither existence nor non-existence. There was no space nor was there anything beyond. (In such a situation) what should encompass (what)? For whose benefit? Was there the dense and deep water?"*

*"Who will tell in detail how and from where came the expanse of the existing? Who knows for sure? Even Gods came after creation. So who would know wherefrom the creation came?"*

These are fundamental questions which are being asked even by present day cosmologists. Humans however are not satisfied by only asking questions. One must have answers too — and if one cannot get them one tries to concoct some. So out of questions like these arose answers that were believed by many to be right. There were no scientific proofs for them but nevertheless they became part of the mythology and gained intellectual acceptance.

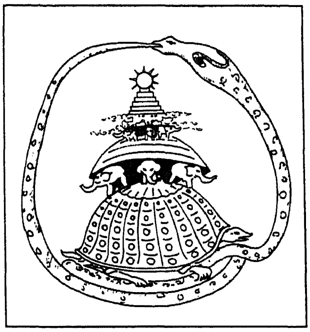

***Figure 1** A hierarchical cosmos: One of our many ancient speculations in India described the earth as resting on elephants, standing on a giant tortoise that was carried by a snake eating its own tail. We will come back to this picture in the final article in this series.*

It was during the Greek civilization a few centuries before Christ, that such speculations began to be viewed somewhat scientifically. The Pythagoreans — the followers of the Greek mathematician and philosopher Pythagoras — were worried about the sun-earth relationship. They refused to accept that the earth goes around the sun (or even vice versa!). Instead they believed that the earth goes around a central fire located elsewhere. The theory predictably ran into difficulty because of the obvious question: "Why don't we see this fire?" To answer this question, the Pythagoreans invented a 'counter-earth' that went around the central fire but in a smaller orbit. This orbit, they said, synchronized with the earth's orbit in such a way that it always managed to block the view of the central fire from anywhere on earth.

The symptom of a wrong scientific theory is that to keep its prediction intact additional assumptions have to be made. Subsequently even these assumptions become untenable. The

Pythagorean theory was of this type. First there was the difficulty of the central fire not being seen. Next came the problem of why the counter-earth is not seen...and so on. However in spite of our criticism of the theory from hindsight it had the merit that it was a disprovable hypothesis.

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Karl Popper, the philosopher of science, has laid down this criterion for a scientific theory: it should be testable and in principle disprovable. In other words we should be able to think of a test whose outcome could rule out the theory. If the outcome does not disprove it the theory survives — until somebody can think of another more stringent test. Popper's criterion provides us with a way of distinguishing between philosophical speculation and a scientific theory.

## Aristotle's Universe

Aristotle, another Greek philosopher, provided a series of principles that in today's parlance could be called a physical theory. He was a pupil of the famous philosopher Plato and the teacher of Alexander the Great. Today Aristotle's ideas are known to be wrong. Yet we should look upon them as man's first attempt at quantifying the laws that govern observed phenomena. The key to Aristotle's ideas lies in his classification of different types of motion.

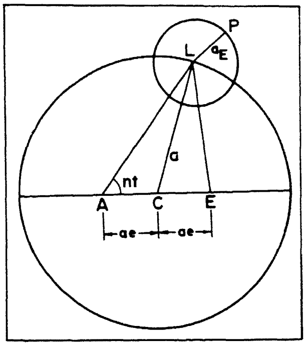


***Figure 2** Epicycles: Example of how, following Aristotle, the Greek astronomer Ptolemy constructed epicycles to explain the motion of a planet P around a fixed earth E. The planet moves on a circle whose centre moves on another circle around the earth. In specific instances several epicycles were needed.*

Aristotle distinguished two types of motion seen in the Universe: *natural motion* which he supposed always to be in circles and *violent motion* which was a departure from circular motion and implied the existence of a disturbing agency. Why circles? Because Aristotle was fascinated by a beautiful property of circles which no other curve seemed to possess. Take any portion of a circle (what we usually call a 'circular arc') and move it anywhere along the circumference: that portion will coincide exactly with the part of the circle underneath it. (The straight line also has this property but it can be considered a circle of infinite radius).

In the jargon of modern theoretical physics the above property

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is one of rotational symmetry. A one-dimensional creature moving along the circumference of a circle will find all locations on it exactly similar, there being no privileged position. As we shall find in the second part of this series, present-day cosmologists employ similar symmetry arguments about the large-scale structure of the universe.

Although the heavenly bodies, especially planets, did not appear to move (naturally) in circles the Aristotelians brought in more complicated geometrical constructions involving a series of circles called epicycles. Thus a planet may move on one epicycle whose centre moves on another epicycle whose centre moves on a third epicycle and so on leading ultimately to a fixed earth in the midst of all these moving real and imaginary points in space.

The epicycle theory was thus no different from the kind of parameter-fitting exercise that goes on in modern times when resolution of apparent conflicts between observations and a favoured theory is sought by introducing adjustable parameters into the theoretical framework. Such an exercise tells us more about the freshly introduced parameters than it does about the basic hypothesis of the original theory. In fact, as with the Greek epicyclic theory a theory, requiring too much patchwork of this sort eventually has to be abandoned.

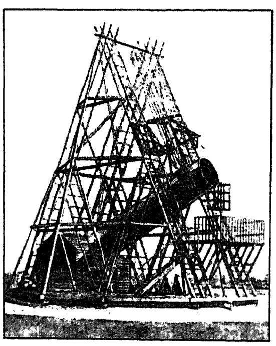

*Figure 3 Herschel's telescope: This major telescope had a tube length of 48 feet and an aperture of 48 inches.*

While it is easy to deride Aristotle and welcome Copernicus, Kepler, Galileo and Newton we must acknowledge that the Greek philosopher originated the notion that natural phenomena follow certain basic rules. Aristotle's perception of such rules turned out to be incorrect but the idea that they exist was carried over and has been the guiding light of theoretical physicists to this day.

## The Advent of Telescopes

The major experimental input to astronomy as a science came in the seventeenth century with the discovery of the telescope. It was Galileo who first used the telescope for astronomical purposes and

who first appreciated its value in observing remote heavenly bodies. Today we would not be discussing the subject of cosmology had there been no telescopes to give us a view of the universe.

No one appreciated the usefulness of the telescope more than William Herschel. A busy music master at Bath in England, Herschel was known for his organ recitals and his huge orchestras. At the age of thirty-five he decided to become an astronomer largely as a result of night-time reading of books on mathematics and astronomy. Herschel's interest was in observational astronomy and starting with a small telescope he eventually went on to build the great reflecting telescope of 48-inch diameter.

**The telescopic investigations of William Herschel and his son John led them to the first crude picture of our galaxy as a disc like system of stars encompassed by the white band known as the Milky way.**

The telescopic investigations of William Herschel and his son John led them to the first crude picture of our galaxy as a disc-like system of stars encompassed by the white band known as the Milky way. By examining the distribution of stars away from the Sun in all directions the Herschels concluded that the sun was at the centre of the galaxy. Thus although it was known in the nineteenth century that the sun is just a common star which appears to be the brightest object in the sky only because it is the nearest, it still retained the special status of being at the centre of the galaxy.

## Our Galaxy

This picture of the galaxy so methodically built up by the Herschels still had two defects which were not corrected until much later at the beginning of the present century. But even in the eighteenth and nineteenth centuries there were those who suspected that something was wrong and whose perceptions came remarkably

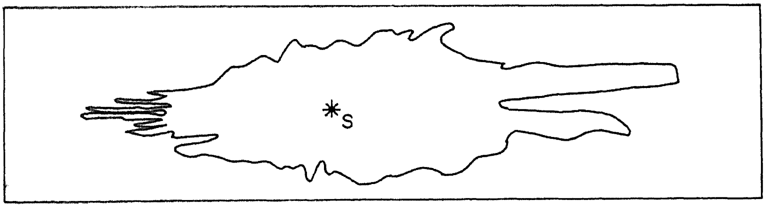


*Figure 4 This map of our galaxy as prepared by William Herschel had the sun S at its centre.*

**Even as late as 1920, astronomers clung to the picture of our galaxy with the sun not too far removed from the centre.**

close to the truth as we now know it. The mathematician J M Lambert suggested for example that the stars in the Milky Way are in motion around a common centre and that the sun along with the planets also moves around this galactic centre.

Lambert also suggested that not all visible objects are confined to our galaxy. In addition to stars and planets astronomers had also found diffuse nebulae whose nature was not clear. Were they far-away clusters of stars or were they nearby clouds of luminous gas? Lambert argued that the nebulae were indeed very distant objects far beyond the galaxy.

Even as late as 1910-20 astronomers clung to the picture of our galaxy as developed by Herschel. For instance J C Kapteyn used the new technique of photography which proved to be a boon to astronomy and arrived at a model of our galaxy as a flattened spheroidal system about five times larger along the galactic plane than in the direction perpendicular to it. In this model commonly known as the Kapteyn Universe the sun was located slightly out of the galactic plane at a distance of some 2000 light-years from the centre (one light-year is the distance travelled by light in one year and this is approximately $10^{13}$ kilometers). The Sun was thus not too far from the galactic centre just as Herschel had proposed.

When Kapteyn's work was published in 1920-22 it was already being challenged by Harlow Shapley. In a series of papers published during 1915-19, Shapley studied the distribution of large dense collections of stars called globular clusters. A globular cluster may contain upto a million stars and can be identified from a distance because of its brightness and distinctive appearance. Shapley found that the number of globular clusters falls of as one moves perpendicularly away from the galactic plane. Along the plane they seemed concentrated in the direction of the constellation of Sagittarius. Shapley therefore assumed that the galactic centre lay in that direction well away from the sun and estimated that the sun's distance from the centre was 50 000 light years. The modern estimate of this distance is only about 60 percent of this

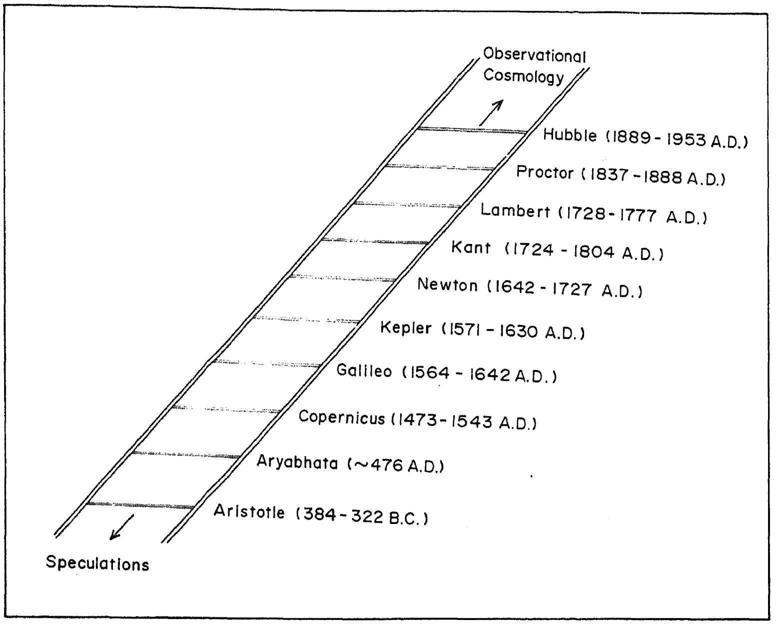


*Figure 5 Progress of cosmology: This ladder-like figure shows how ideas on the cosmos received major inputs. Some of them have been mentioned in the text. In addition, Aryabhata was aware of the earth's spin about its axis, which according to him explained why fixed stars appear to travel westward; Kant and Proctor had suggested that our galaxy is just one among many.*

value but the sun does go around the galactic centre as guessed correctly by Lambert. The total diameter of the galaxy is about 100 000 light years and it contains some 100-200 billion stars.

While Shapley was right in dethroning the sun from its presumed privileged position at the centre of the galaxy his distance estimates were too large because he ignored the effects of interstellar absorption. Nor did Shapley agree with Lambert's view that most of the diffuse nebulae lay outside the galaxy. But by the 1920s the obscuring role of the dust began to be under stood and the picture of our galaxy underwent a drastic change. Many stars which were earlier believed to be far away because they looked faint were discovered to be much nearer, their faintness being due to absorption by the interstellar dust. Even more important was the conclusion that many of the diffuse nebulae lay far away, well outside the galaxy. Indeed it soon became apparent, thanks largely to the work of Edwin Hubble, that these nebulae were galaxies in their own right as large as our own which are moving away from our galaxy at very large speeds. It was Hubble who found an empirical law governing their motion that was to become the foundation for modern cosmology.

**Suggested reading**

**H Bondi. Cosmology. Cambridge University. 1960.**

**J V Narlikar. The Lighter Side of Gravity. W H Freeman and Co. 1982.**

**F Hoyle. Astronomy and Cosmology - A Modern Course. W H Freeman and Co. 1975.**

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# Life : Complexity and Diversity

## 1. A World in Flux

*Madhav Gadgil*

Madhav Gadgil is with the Centre for Ecological Sciences, Indian Institute of Science and Jawaharlal Nehru Centre for Advanced Scientific Research, Bangalore. His fascination for the diversity of life has prompted him to study a whole range of life forms from paper wasps to anchovies, mynas to elephants, goldenrods to bamboos.

**Evolving patterns of matter and energy gave rise to the cosmos. The earth, itself a dynamic entity, is inhabited by living organisms that have a dialectical relationship with the world around them.**

### Cosmic Dance

We live in a world in flux. In a world of ever changing patterns. Patterns that change with the time of the day, the season of the year. Patterns that change from place to place. Patterns that have been in flux ever since the cosmos originated with a big bang fifteen billion years ago. In the beginning was pure energy concentrated in an infinitesimally small space. As the cosmos expanded, matter began to crystallize out of this cauldron. First as tiny elementary particles, each on its own, each dancing separately. As things cooled down, the particles linked arms to form atoms. Initially smaller ones, like hydrogen, helium, oxygen, later larger ones, such as iron or nickel. With time these atoms began to form complexes, molecules like those of water, as well as larger entities like crystals and metals.

Slowly matter condensed to form heavenly bodies: nebulae, stars, planets, meteorites. All the while atoms were bumping into each other, linking together to form bigger and bigger molecules. Of all the variety of atoms, carbon and silicon are best at holding hands with each other, and with those of other kinds as well. Like Brahma and Vishnu, our gods of creation and maintenance, they have four arms each. So not only can they form long carbon or silicon chains, but a variety of side chains, with hydrogen, oxygen, nitrogen, even iron or manganese. The chains so formed can twist and wrap around each other, forming balls with a multitude of

projections and indentations. Thus is formed an incredible diversity of carbon-containing, or organic, molecules. Molecules predominantly composed of silicon tend to form more regular sheets and three dimensional structures, giving rise to particles of sand and crystals of quartz.

But atoms can hold hands with each other only when the surroundings are cool enough. When things heat up too much they delink, preferring to dance on their own. At extreme temperatures they even lose their shells of electrons - the tiny particles that whirr around the nucleus of each atom. As a result, a large variety of carbon containing molecules can only be formed at moderate temperatures, indeed just such temperatures as we enjoy at the surface of the earth. Not that the rest of the cosmos has no organic molecules; in fact there are some even in the wide open spaces between the stars. Some pretty large organic molecules also occur on meteorites called carbonaceous chondrites. But earth has in abundance one other substance that makes all the difference. This is liquid water. This is because organic molecules move around with the greatest ease when immersed in water. Then they can twist and turn, taking on myriad shapes. And they can really play with each other, zipping and unzipping chains, chopping off a piece here, adding on a piece there. Swimming in water, the organic molecules have let themselves go, eventually coming together to form the truly marvellous structures that living organisms are. Life thus owes its origin to the great good fortune that on the surface of the earth prevail temperatures that permit water to remain for much of the time in its liquid form.

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## Dynamic Earth

The earth on which this dance of organic molecules is in progress, is itself a dynamic entity. On it the water is forever in flux, passing between its liquid and vapour forms; giving rise to clouds and rain, rivers and seas. More than two thirds of the earth's surface is today covered by the seas; seas that have been there a long, long time. An average cloud on the other hand survives no more than

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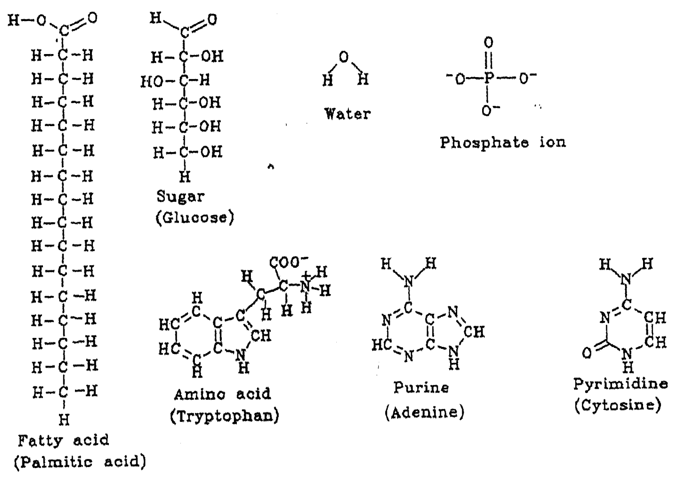
an hour or so; larger collections of clouds persist for at most a few days. But we now know that seas and islands, continents and mountains are also subject to change, albeit on a much slower time scale. For, the continual barrage of rain and wind on the surface wears the land down; and the flux of hot molten rocks in the interior of the earth raises it back again. Even more significantly, this flux of hot molten rocks in the bowels of the earth drives around whole plates of land and ocean floor, so that continents go on forming, splitting, reforming, albeit on a time scale of hundreds of millions of years.

The rich kaleidoscope of patterns of nature that we witness all around us, every moment of our lives, is then a dance of organic molecules, in a watery medium, set in a theatre that is itself changing slowly but irrevocably, all the time. The dance patterns have been changing in all of the four and a half billion years that the planet earth has been in existence. The pace of change quickened a little when life first appeared on the scene three and a half billion years ago. It accelerated further when life invaded land four hundred million years ago. When tool-using ancestors of humans first appeared on the scene two million years ago, there was little reason to believe that the world was getting set for a dramatic increase in the rate of change in the manifold patterns of nature. But that has come to pass, and today we humans are a dominant force governing the variegated mosaic of nature.

## Molecules of Life

The most fascinating, the most complex, the most diverse of patterns of nature are the handiwork of living organisms. Living organisms might be thought of as co-operative teams of complex organic molecules that take in matter and energy from their surroundings, and use these to keep themselves in good repair as well as to make more copies of themselves. The set of complex molecules constituting these co-operative teams is ultimately fashioned out of a small number, a few hundred basic building blocks. These include water, phosphate ions and four main types

**Building Blocks of Life**




of organic molecules: sugars, fatty acids, amino acids and purine and pyrimidine bases. Some of these organic molecules, such as adenine or ribose have 15 to 20 atoms, while others such as palmitic or stearic acid have 50 to 60 atoms. Each such building block is made up of at least three elements, carbon, hydrogen and oxygen and may additionally include nitrogen, phosphorus or sulphur. But these small numbers of a limited variety of atoms are linked to each other in very specific orders. That gives rise to the possibilities of fabricating a great diversity of molecules, sometimes differing only slightly from each other. Thus in amino acids one of the carbon atoms is linked to four distinct entities: H, $NH_3^+$, $COO^-$ and a longer residue. This allows the formation of two forms which although identical in composition are mirror images of each other *(Figure 1)*. Notably enough all amino acids in living organisms exhibit only one of the mirror images, the L-form. These building blocks can of course be further linked together to form larger, more complex formations. Thus proteins, amongst the most vital of the larger molecules of life, are formed by linking together several amino acids in long chains. Now consider the great variety of such chains that may be formed by choosing one out of twenty amino acids in each position. With just

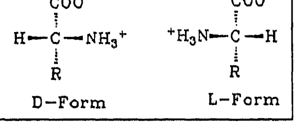



***Figure 1** The D-form and L-form of amino acids are identical in composition but mirror images of each other. All living organisms exhibit only the L-form.*

**Table 1 Chemical composition of cells of living organisms**

| Constituent | Number of atoms per molecule | Estimated number of varieties of each molecule | |
|---|---|---|---|
| | | Bacteria | Mammals |
| Water | 3 | 1 | 1 |
| Inorganic ions | 1-5 | 20 | 20 |
| Sugars and precursors | 10-30 | 200 | 200 |
| Amino acids and precursors | 10-30 | 100 | 100 |
| Nucleotides and precursors | 30-50 | 200 | 200 |
| Lipids and precursors | ~ 50 | 50 | 50 |
| Other small molecules | ~ 100 | 200 | 200 |
| Polysaccharides | > 1000 | 100 | 1000 |
| Proteins | 1000- 5000 | 4000 | 100000 |
| rRNA | 3200- 96000 | 6 | 6 |
| tRNA | ~ 5000 | 20 | 20 |
| mRNA | 2500-25000 | 1000 | 100000 |
| DNA | $10^9$-$10^{12}$ | 1 | 20* |

**This number varies from species to species.*

**Proteins are made up of tens if not hundreds, of amino acids, making possible millions upon millions of different combinations.**

two amino acids linked together there are 20 x 20 or 400 possibilities. With three, 400 x 20 or 8000, with four, 8000 x 20 or one lakh sixty thousand. Proteins in fact are made up of tens, if not hundreds of amino acids, making possible millions upon millions of different combinations. The chains of proteins thus formed do not remain as long strings. They fold up, forming complex globular, ovoidal bodies. The shapes of these bodies are governed by the sequence of amino acids in the chain, so that a whole variety of intricate shapes can be generated by just varying the order in which the amino acids are linked one after another. And not only do these larger molecules come in many different, elaborate shapes, they bear on their surfaces intricate patterns of positive and negative electrical charges. Like proteins, other building blocks of life are also linked together in many different ways, but

each in some precise order to form larger molecules. Thus many sugar molecules form polysaccharides, starches, cellulose, fatty acid molecules to constitute lipids, or along with sugars and phosphates glycolipids or phospholipids. Purine and pyrimidine bases are joined to sugar and phosphate to constitute nucleotides and nucleotides are linked into long chains to constitute nucleic acids.

Each of these molecules, large and small, play a particular role in the co-operative team of the molecules to allow the team to take in matter and energy in appropriate forms, to keep the team in good repair and to make more copies of themselves. This is an elaborate exercise which requires the co-operation of thousands of different molecules. *Table 1* looks at the composition of such teams for one of the most ancient forms of life, bacteria, and one of the most recent, mammals. The diversity of simpler building blocks is essentially the same for bacteria and mammals. The larger molecules however, are markedly more diverse, by one or two orders of magnitude in the case of mammals.

**Once triggered off in the hoary old times three and a half billion years ago, the dance of life has become more and more elaborate, drawing in an ever larger number and variety of actors.**

Once triggered off in the hoary old times three and a half billion years ago, the dance of life has become more and more elaborate, drawing in an ever larger number and variety of actors. And the stage over which they have been dancing has also gone on expanding, beginning with shallow seas, invading depths of ocean, land, air and finally outer space.

## Suggested Reading


B Alberts, D Bray, J Lewis, M Raff, K Roberts, J D Watson. Molecular Biology of the Cell. Garland Publishing, Inc. New York and London. pp. 1146. 1983.

R Cowen, History of Life. Blackwell Scientific Publications. pp. 470. 1990.

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# Algorithms

## 1. Introduction to Algorithms

*R K Shyamasundar*

R K Shyamasundar is a Professor of Computer Science at TIFR, Bombay who has done extensive research in various foundation areas of computer science.

**In this introductory article the concept of algorithm which forms the foundation of computer science is defined. A diagrammatic form of describing algorithms known as flow-charts is introduced and used to express some elementary algorithms.**

### What is an Algorithm?

The concept of an *algorithm* constitutes the foundation for information processing. It is not only a familiar concept to mathematicians but also forms the foundation of computer science. Two striking features of algorithms are: 1) an algorithm is meant to be *executed* and 2) objects underlying an algorithm have an *associated meaning*. In the first few articles, our exploration is confined to the first feature.

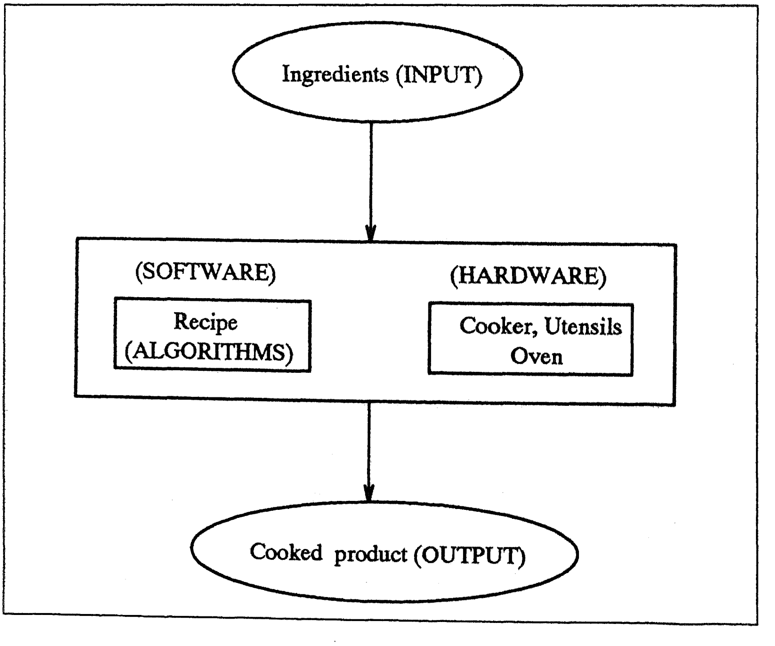



***Figure 1** A computational process is similar to the process of cooking.*

**About the series on "Algorithms"**

Algorithms are central to the applications of computers and were proposed well before the advent of computers. A well-known algorithm by Euclid gave a step by step method to find the greatest common divisor of two numbers. The study of algorithms as a subject became important with the advent of computers. The science of "algorithms" deals not only with methods of developing algorithms for solving a variety of problems but also with fundamental questions such as: "are there problems for which algorithms do not exist?", "even if algorithms exist will they lead to solutions within a reasonable time?", "are there systematic methods of proving whether an algorithm, to solve a problem, is correct?".

In this series of articles a variety of topics will be discussed. After discussing some well-known algorithms in depth, algorithmic methods which can be systematically applied to solve problems, methods of proving correctness of algorithms and finding out the complexity of algorithms will be discussed. Some interesting theoretical questions regarding computability which students find difficult to understand will be explained.

Computer scientists have largely devoted their attention to non-numeric algorithms. When it comes to applications of computers in science and engineering, numerical algorithms, namely, those related to numerical calculus are as important. We will thus discuss some interesting issues in evolving numerical algorithms. As the topics discussed are diverse many individuals with expertise in the topics they write about will author this series.

*V Rajaraman*

Consider the process of cooking rice. Cooking is the process carried out by a cook using the ingredients with the help of utensils, cookers, oven and a *recipe*. The ingredients are the *inputs* to the process, the cooked rice is its output, and the *recipe* is its *algorithm*. That is, an algorithm prescribes the activities that constitute a process. The recipes (algorithms) are grouped under the term *software*, whereas the utensils, cookers, and oven are grouped under *hardware*. The process of cooking is depicted in *Figure 1*.

**Two striking features of algorithms are: 1) an algorithm is meant to be *executed* and 2) objects underlying an algorithm have an *associated meaning*.**

Let us look at a recipe for cooking rice. It consists of the following simple activities:

1 Put 1 cup of rice in the vessel of an electric rice-cooker.
2 Put 2 cups of water in the cooker vessel.
3 Close the lid of the cooker and switch it on.
4 Wait until the indicator light of the rice-cooker turns off.

**History**

The word 'algorithm' itself is interesting. At first glance, it appears to have some relation to the familiar 'logarithm' (by some permutation of the first four characters). However, it stems from the name of the author of a famous Arabic textbook ( its original Arabic text is lost; a Russian translation of a Latin manuscript exists), Abu Ja'far Mohammed ibn Mûsā-al-Khowārizmī (A D 825) who first suggested a mechanical method for adding two numbers represented in the Hindu positional number system. The name transcribed in Latin became *algorismus* from which *algorithm* was but a simple transformation. Of course, the first non-trivial algorithm ever was devised by the great Greek mathematician Euclid (between 400 and 300 B C) for finding the greatest common divisor (gcd) of two positive numbers. The word 'algorithm' was most often associated with this algorithm till 1950. It may however be pointed out that several non-trivial algorithms such as synthetic (polynomial) division have been found in *Vedic Mathematics* which are dated much before Euclid's algorithm.

From activities 1-3, we can observe that:

- Each activity is a command.
- Each activity is finite and unambiguous (assuming that a cup and an electric cooker are given).
- Activities 1 to 3 are done in sequence. That is, activity 1 is followed by activity 2; it is only then that activity 3 is performed.

**A *programming language* is used to describe an algorithm for execution on a computer. An algorithm expressed using a programming language is called a *program.***

It can be easily seen that activity 4 is a "test" rather than a command. Further, we cannot conclude that the light indeed turns off - that is, whether the activity terminates. However, assuming the cooker to be non-faulty and does cook (even if it is slow), we know that activity 4 eventually terminates. In the same way, one of the most important aspects of an algorithm is that it should always terminate after a finite number of steps. In short, we can say that an algorithm is a finite set of rules that prescribes a sequence of operations for solving a specific problem. Though this is not a formal definition, it captures the concepts underlying algorithms.

As already emphasized, we would like our algorithms to *execute* on a processor. Hence, it can be easily seen that the notation used for

describing the algorithm has to be precise and unambiguous. From the above discussions regarding the recipe for cooking rice, we can see that the notation (essentially the language) used for describing algorithms should have the following properties:

1 All the basic operations used to describe the algorithmic steps must be capable of being performed mechanically (without using any intuition) in a finite amount of time.
2 Each step must be defined unambiguously.
3 The language must be general enough for describing different kinds of algorithms that can operate on a variety of inputs.
4 It should be capable of describing steps which provide input and extract outputs.

To reiterate, the algorithms must be written in an unambiguous and a formal way. A *programming language* is used to describe an algorithm for execution on a computer. An algorithm expressed using a programming language is called a *program.*

## A Flowchart Language

Let us now look at a visual and diagrammatic form of describing algorithms. The essential components of a visual diagrammatic representation referred to as *flowcharts* will be described now:

*Basic Commands*

The basic commands are denoted by a rectangular box with an inscription of the operations to be performed. For example, *Figures 2(a)-(c)* correspond to setting the value of *i* to 1, setting the value of *c* to the sum of values of *a* and *b*, and setting the value of *x* to *sin(theta)* respectively. *Figures 2(d) and 2(e)* denote commands to read in values into A,B,C and printing the values of *x, y,* and *z* respectively. Observe that *parallelograms* are used to represent Read and Print commands. Further, it is useful to denote a command which does nothing by an empty box or a box with an inscription *nothing.*

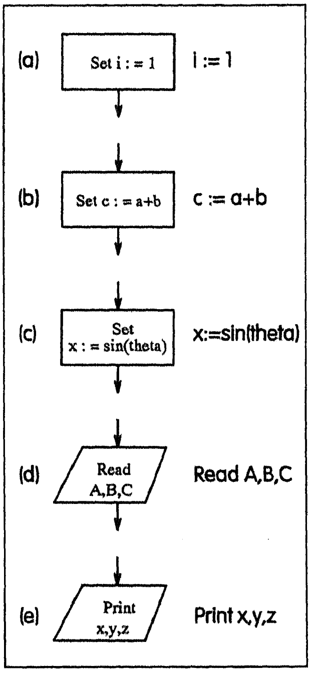



***Figure 2** Symbols used in flowchart language to represent Assignment, Read and Print commands.*

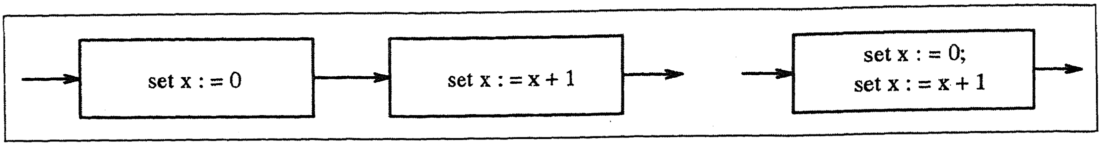



***Figure 3** A sequential composition allows building a larger component using smaller components.*

Another point to be observed is that one arrow leads into the box and another arrows goes out of the box. The arrow at the top of the box can be visualized as a way of asking the processor to do the prescribed action, and the arrow at the bottom is a way of signalling the environment that the prescribed action is done.

These are referred to as the command actions. In textual form the commands would merely be those inscribed within the box; these are shown on the right half of Figure 2. The operator ": =" is referred to as the "assignment" operator and is interpreted as:

> "Assign the value of the *expression* (operand) on the right-side of the operator, to the *variable* (operand) on the left-side of the operator".

*Sequential Composition*

The operation of 'sequencing' permits concatenation of boxes; that is, the operation provides a way of 'composing' or 'building' a program (system) from smaller components.

For example, the left-part of *Figure 3* corresponds to first setting the 'variable' $x$ to zero and then assigning to $x$ the value obtained by adding 1 to the old value of $x$ (i.e. increment $x$ by 1). For brevity, we denote the same by the box shown on the right side of Figure 3. Here, the order is implicitly indicated by the top-down order. Sometimes, a semicolon is used to separate the commands in order to avoid confusion.

It is important to note that $x := 0$; $x := x + 1$ is not the same as $x := x + 1$; $x := 0$. In the former, after the execution is complete, $x$ will have the value 1 and in the latter, $x$ will have the value 0. Thus, the order of the commands is important.

*Test*

'Test' is denoted by a *diamond box* having one input arrow and two output arrows as shown in *Figure 4*. Note that if $x > 100$ then the control goes to the branch labelled "YES", and if $x \leq 100$ (i.e., negation of the condition $x > 100$), then the control goes to the branch labelled "NO".

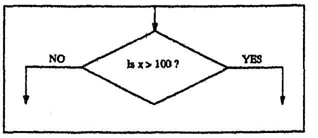



***Figure 4** A diamond shaped box is used to represent a test.*

A construct called "if-then-else" is shown in *Figure 5*. Observe that if the 'cond' test is "true" the "YES" path is taken and if it is "false" the "NO" path is taken. In the "YES" path statement 1 is executed and in the "NO" path statement 2 is executed.The flowchart can be thought of as a 'block' as it occurs often in algorithms. It can be concisely expressed using an algorithmic language as shown below:

```
if cond  then Statement 1
         else Statement 2
endif
```

This is a single statement.

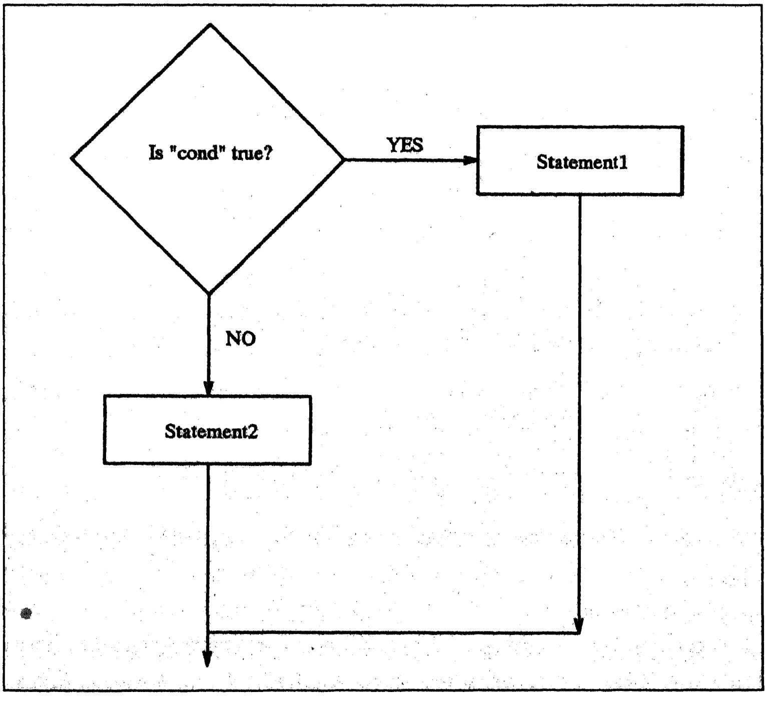



***Figure 5** A flowchart illustrating a commonly used algorithmic construct known as if-then-else.*

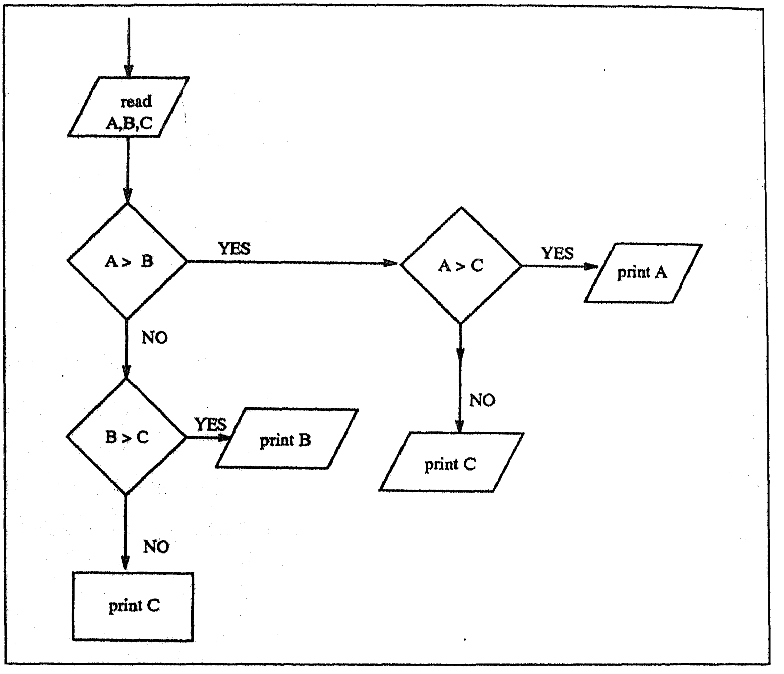



*Figure 6 A flowchart which describes an algorithm to find the largest of three numbers.*


## Suggested Reading

D E Knuth. Art of Computer Programming — Volume 1. Addison-Wesley Publishing Co. 1972. This volume, which discusses fundamental algorithms, is an advanced and authoritative book on the subject.

E W Dijkstra. A Short Introduction to the Art of Programming. Computer Society of India. 1977. This is a lucid article written by a pioneer whose research work formed the basis for transforming programming from an art to science.

G Polya. How to Solve It. Princeton University Press. 1973. Even though this book does not deal with computational algorithms it is recommended reading as it provides insights into the process of problem solving.

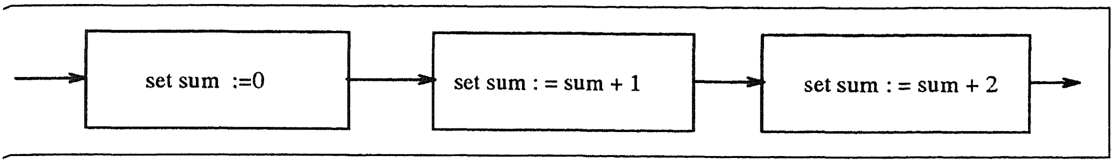
R G Dromey. How to Solve it by Computer. Prentice-Hall of India, New Delhi. 1990. Following Polya's philosophy, this book explains approaches to problem solving algorithmically.


Note that *Statement 1* or *Statement 2* can themselves be composed of many basic commands. Whenever the command is not primitive (made of at least two basic commands), we often refer to the statement as a "block".

Note also that apart from the basic commands, we use a beginning-keyword (such as "*if*") and corresponding matching end-keyword (eg., "*endif*"). This would aid readability of the program (similar to open and close parenthesis) and also enables us to use blocks of statements between the beginning-and end-keywords. For instance, in the "*if-then-else*" construct, the keyword, "*endif*" corresponds to the end for the whole construct; further the keyword "*then*" closes with "*else*", the "*else*" closes with "*endif*". In the programs shown, we have also used "indentation" to highlight the blocks (this aids in reading programs).

*Example 1: Given three distinct numbers A,B,C find the largest among them.*

In the flowchart shown in *Figure 6*, one can trace the paths from the start (from the beginning of the read-block) to the end (print-




lock) and can observe that the path is finite. The path passing hrough the edges "YES, YES" satisfies the condition $A > B$ and $1 > C$ and hence we can conclude that A is the largest. The second ath passing through the edges "YES, NO" satisfies the conditions $A > B$, and $A \leq C$ respectively and we can conclude that C s the largest. Similar assertions follow along the same lines on ther branches.

**Figure 7** *A flowchart to sum the first two natural numbers.*

The following observations can be made on this algorithm:

1. The algorithm terminates as each path is finite and each block can take only a finite amount of time.
2. The number of boxes that get executed in each path can be fixed before accepting (reading) the values of A, B and C. In other words, the number of boxes in each path is fixed.

However, it is not always possible to satisfy property (2) as llustrated by the following example.

*Example 2: Summing N Numbers: The problem is to find the sum of the irst N natural numbers (i.e., the set {1,2,3,...N}) for any given N.*

Let us first write a flowchart for the case $N = 2$. Next the required lgorithm can be derived from this flowchart as shown in *Figure 7*.

Thus, if we have to sum the first 100 numbers, we need 100 + 1 boxes. This is not a very elegant way to solve the problem. Then the natural question is: Is it possible to obtain a flow chart which has the same number of boxes, irrespective of the value of $N$? The answer is "yes", and the solution lies in the construct wherein the number of times a set of commands gets executed depends on the values of certain variables. We will discuss this in the next article n this series.

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The material in this series of articles is based on the works of a large number of researchers - too numerous to cite individually. I thank N Raja and Basant Rajan for a critical reading of the manuscript.

*R K Shyamasundar*

# Fascinating Organic Transformations: Rational Mechanistic Analysis

## 1. The Wagner Meerwein Rearrangement and the Wandering Bonds

*Subramania Ranganathan*

**A carbocation can stabilize itself by a series of C-H and C-C shifts to reach the most stable form. Several examples are shown in which relatively strained systems upon such cationic rearrangements produce diamondoid systems.**

**After nearly a three-decade long innings as an inspiring teacher and researcher at IIT Kanpur, S Ranganathan is now at RRL, Trivandrum. He and his chemist wife, Darshan, plan to set up (without government assistance) "Vidyanantha Education Centre", to promote education, art and culture.**

The Ganges flows to neutralize the water potential, electricity flows to compensate an electron gradient. Naturally therefore, an electron deficiency in a carbon framework generates a "bond flow". This phenomenon, in its most simple representation *(Figure 1)*, is the Wagner Meerwein rearrangement.

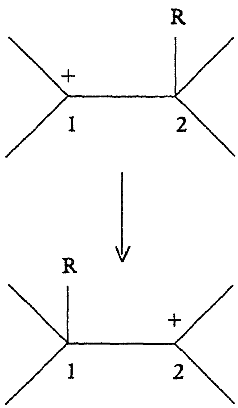


***Figure 1** The Wagner Meerwein rearrangement.*

A natural property of an electron deficient centre is to make the system dynamic, thus opening the possibilities for charge dissipation. This can be illustrated with what is called the Grotus mechanism *(Figure 2)*. One can see how effectively the proton excess on the left side is transmitted by the medium to the right. Similarly, charge deficiency created at a location can be evenly, and quite effectively, spread swiftly. The process that takes place

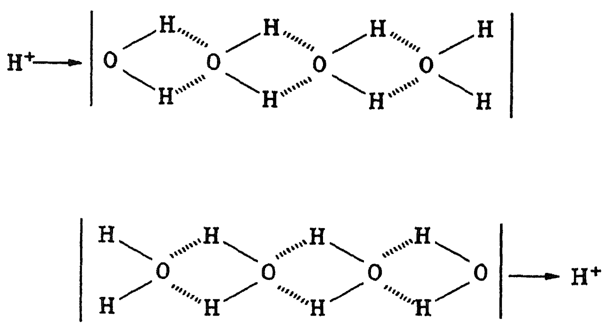


***Figure 2** The Grotus mechanism.*

**The Series on Fascinating Organic Transformations: Rational Mechanistic Analysis**

Rational analysis of organic reaction mechanisms was initiated in the early decades of this century, when the now well-known 'arrow pushing' *, to describe the flow of an electron pair, gained popularity among chemists. Subsequently, in the 1930-1960 period, the combined efforts of several great organic chemists established mechanistic organic chemistry on a firm ground. Every organic transformation is, however, unique, in the sense that there is always some twist when you carry out a new reaction (or else many of us would have been out of business!). Thus, in order to understand new transformations, one must have a very good appreciation of the basic principles of mechanistic analysis.

Many of us feel that at the undergraduate level rational mechanistic analyses of exciting transformations are seldom taught. The examples available in many textbooks tend to be somewhat routine (and perhaps boring), and many good examples are left out. S Ranganathan, one of the most popular organic chemistry teachers at IIT, Kanpur for almost three decades, has put together for ***Resonance*** readers, six examples that demonstrate a step-by-step approach to rationalize fascinating organic transformations.

In this series of articles, he will cover Wagner-Meerwein rearrangement, molecular self- assembly, Woodward-Hoffmann rules, 'lone pairs', von Richter reaction and synthesis vs biosynthesis of indigo. We are certain that students and teachers alike will enjoy the simple and classroom-type discussions provided in each of these examples.

* When organic chemists started using curved arrows a well-known chemist reportedly remarked: "Curved arrows never hit the target".

*Uday Maitra*

in the norbornyl cation system (1, *Figure 3*), leads to a total charge dissipation, as shown in *Figure 4*.

Figures 3,4 permit the definition of very basic aspects associated with this type of bond migrations. By definition, whenever a sigma bond (other than a C-H bond) shifts, it is called the Wagner Meerwein shift [WM]. The hydrogen sigma bond migrations are denoted as proximate [1,2] or through-bridge [1,3] shifts.

The WM shift in substituted derivatives of 1 [1,2 $\rightleftharpoons$ 2,1] takes place with incredible speed*, of the order of $\approx 10^{12}$ $sec^{-1}$ at room temperature [RT]. This is an estimate, since no 'eye' can see this because of the swiftness of the operation. We enjoy the video because we cannot 'see' it! The frames move at a rate faster than the

1,2-alkyl shift ≡ WM and
1,2 $H^-$ shift ≡ [3,2]
1,3 $H^-$ shift ≡ [6,2] if one uses norbornane system.

*The structure of the unsubstituted 2-norbornyl cation is highly controversial. Do 1 and 2 rapidly interconvert or does the ion exist as an intermediate 'non-classical' form? Spectroscopic and theoretical studies are currently interpreted in favour of the latter proposal. However, tertiary derivatives have classical structures and undergo fast WM shifts.

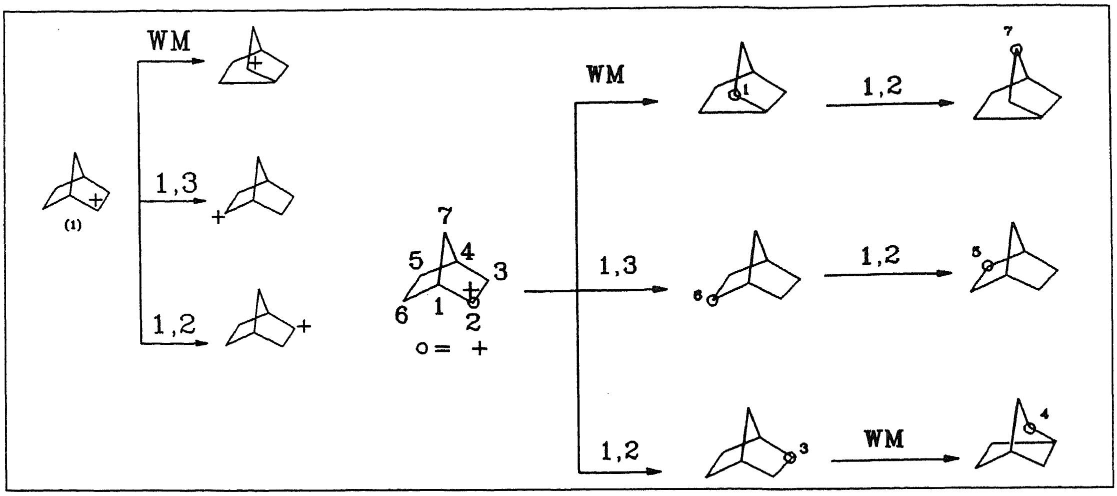



*Figure 3,4 Rearrangements in the norbornyl cation system.*

eye can discern [≈16 frames sec$^{-1}$]; thus one frame merges into another creating an illusion of continuity. At one time the WM in 1 was called the windshield wiper [**WW**] effect. The WW of a car operates (if at all!) at the rate of one per second. So one can see how rapid the WM in 1 is. The [1,3] is slower [≈$10^8$ sec$^{-1}$], and the [1,2] even more so [≈$10^6$ sec$^{-1}$]. The last two could be focused to the eye of the NMR which can distinguish events that take place at $10^4$ sec$^{-1}$. So, cooling down the norbornyl cation 1 can bring down the rates to lie in the vision range of NMR and this has been done. Charge dissipation naturally opens avenues for equilibration leading to stable systems from not so stable precursor cations. This is well documented in organic chemistry, and in this presentation is taken to esoteric heights leading to options for making diamond!

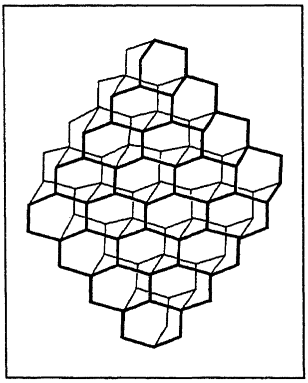
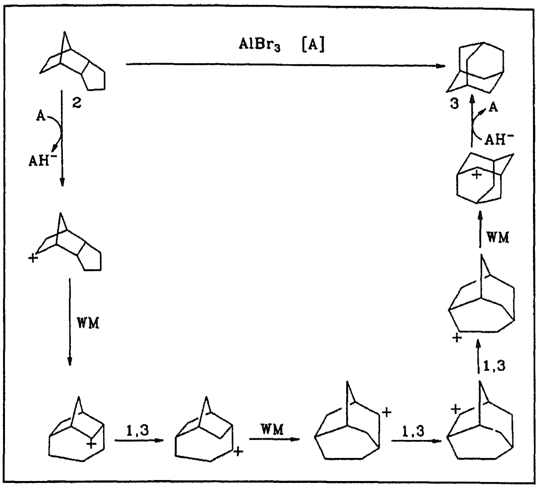
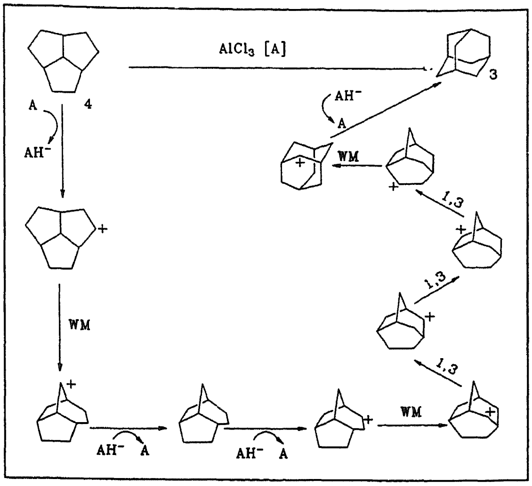


*Figure 5 A profile of the diamond structure. Note how beautifully the chair cyclohexanes are stacked leading to a thermodynamically stable constellation.*

A profile of diamond structure is shown in *Figure 5*. Note how beautifully the chair cyclohexanes are stacked leading to a thermodynamically stable constellation. This would imply that such shuffling of bonds can lead to diamondoids from unrelated precursors having the same carbon framework. This was dramatically illustrated with the transformation of 2 - readily formed by hydrogenation of cyclopentadiene dimer - to adamantane (**3**) in excellent yields, thus making a rather expensive compound very commonplace! Like in a 'random walk jogging' we can start in



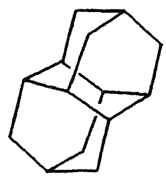




several directions from 2 and reach 3. We have shown here one such pathway (*Figure 6*). One can trace other pathways and doing so can be fun! To reinforce the notion of equilibration leading to diamondoids, another example is given in *Figure 7*, wherein the aesthetically pleasing C-10 triquinane (4) possessing a three fold axis of symmetry, is transformed to adamantane (3).

***Figure 6** (top left) Rearrangement of compound 2 to adamantane (3).*

***Figure 7** (top right) The aesthetically pleasing C-10 triquinane (4) transformed to adamantane (3).*

While adamantane (3) was known before the era of the understanding of carbocation rearrangements, its logical homolog 5, notionally formed by placement of additional chair cyclohexanes was unknown. The fascination for this molecule was such that it was the motif for an international congress (IUPAC Conference in 1963) and the compound itself was named, before birth, as *Congressane;* additionally, a reward was offered for anyone who could make it before the next congress, scheduled in two years. But no one could claim this reward! The facile synthesis of adamantane (3) by wandering of sigma bonds opened up possibilities, not only for congressane, but also for higher members of the family. In the event, congressane, now formally called diamantane (5) was magically made, in excellent yields from 6 and 7 which are easily derived from the dimerization of the C-7 bicycloheptadiene. Indeed, dimer 6 gave a 90% yield of 5 under equilibrating conditions! The transformation of 6 and 7 to diamantane (5) has been rationalized in *Figure 8* and *Figure 9*, respectively, by pathways



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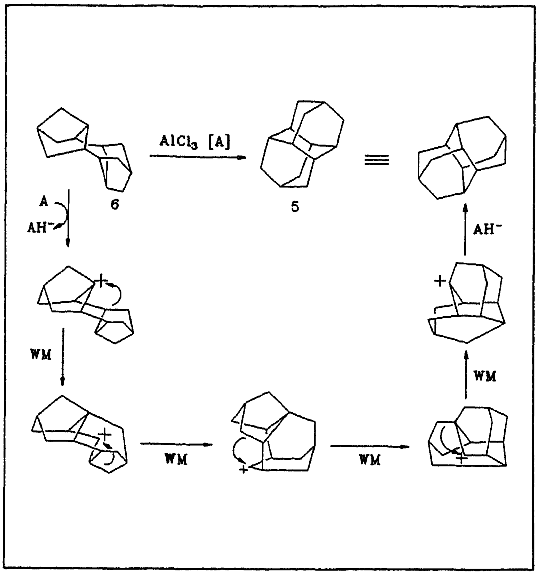
**The fascination for the logical homolog 5 of adamantane (3) was such that it was the motif for an international congress (IUPAC Conference in 1963)**



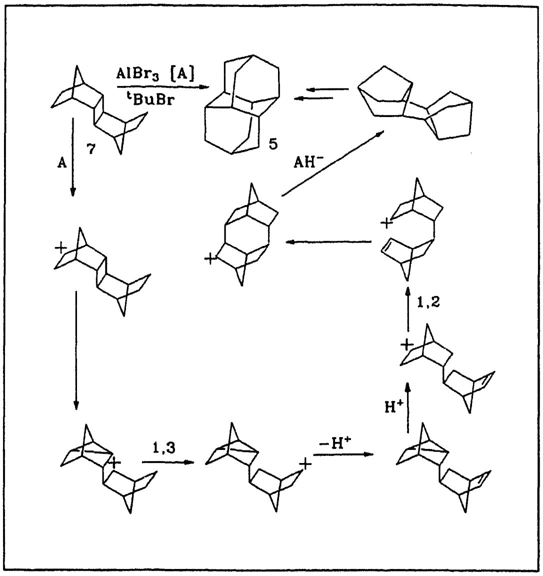
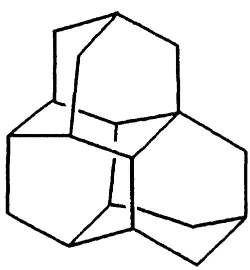




***Figure 8,9 Rearrangement (top left) of compound (6) and (top right) compound 7 to diamantane (5).***

precisely similar to those discussed earlier. A recent addition to this family is triamantane (8), which has a true tetrahedral carbon, attached to four other carbons as in diamond.



8

***Figure 10 Triamantane (8).***

Based on the above principles and illustrations, one could develop a computer program to identify appropriate precursors for a

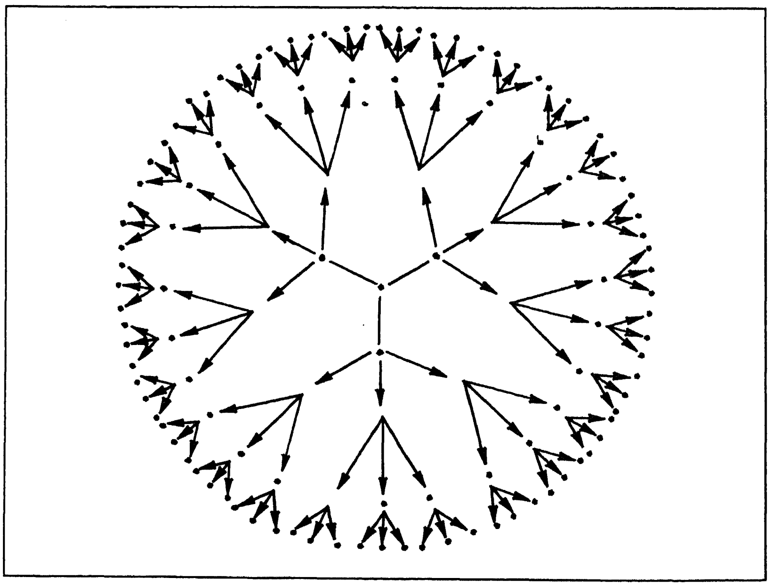


***Figure 11 (right). Iterative pattern search for diamandoid precursors on the basis of a retro-analysis program.***

specific diamondoid. Even in the case of C-10 adamantane (3), the number of possible C-10 precursors would be huge. For higher members of the series the options could be astronomical. A reasonable guess is that it would take 500-1000 such rearrangements for substances that would have the properties of diamond. Thus it is obvious that if the carbocation strategy is to be adopted to make diamondoids, a listing of all possible precursors be secured using a computer and based on the three pathways involved. The task could be simplified by incorporating restrictions in the program. Although using this strategy for diamond appears far fetched, it could lead to novel diamondoids and related precursors having desirable properties. The iterative pattern is simple, and each generation produces three possibilities, as shown in *Figure 11* (the three arrows here represent, WM, [1,3] and [1,2]).

**One could develop a computer program to identify appropriate precursors for a specific diamondoid.**

## Suggested Reading

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**Newton's Inheritance ...** After Newton's death on 20 March 1727, his liquid assets, which totalled some £32,000 were to be divided equally among his eight nieces and nephews, but the estate at Woolsthorpe was now legally the property of the next surviving Newton. He turned out to be one John Newton, descendant of a brother to Newton's father, who was described as "a poor representative of so great a man". This assessment proved to be accurate: John Newton gambled and drank his inheritance away, dying by accident when, after a round of drinking, he stumbled and fell with a pipe in his mouth, the broken stem lodging in his throat.

# Geometry

## 1. The Beginnings

*Kapil H Paranjape*

After spending about a decade at the School of Mathematics, TIFR, Bombay, Kapil H Paranjape is currently with Indian Statistical Institute, Bangalore.

**Mathematics is as much an art as a science. Thus to understand why we study the problems we do today we must examine the history of the subject. In this series of articles we will try to examine how the geometric concepts that are in use today evolved. (A note of warning: the 'history' here is more a personal view than a historian's.) As in art, understanding is enhanced by doing. Readers are encouraged to attempt the exercises scattered in the text.**

### The Origin (s)

**Origin:** the starting point of a flow *or* the centre of a coordinate system.

We are often told that geometry (=geo+metry) arose out of the attempt to measure land area. But this view ignores the development of geometry for navigation by travellers who used stars, for the design of buildings, in art and painting and so on. In fact geometry and geometrical thinking is one of the fundamental activities of the brain — the other being algebraic thinking (these two modes are sometimes called the spatial and verbal functions of the brain).

**An important mathematical feature of Euclid's theory is that rules of deduction are very strict; nothing — not even so-called common sense or intuition — can be taken for granted.**

The first comprehensive treatment of geometry which we can call *mathematical* from a modern perspective is that of Euclid. From a few basic concepts (point, line, angle etc.) and few basic statements (the five axioms) he wished to deduce *all* the known (geometrical) phenomena using some logical principles (which he called common notions). In other words he was constructing a 'theory of everything'. At the same time he was aware that our 'imperfect' world did not quite meet all the requirements — the truly geometric world was the Platonic universe of the heavens; a

**Table 1. Hilbert's Axioms for Euclidean Geometry**

1) Incidence. Each pair of distinct points determines a unique line and so on.
2) Separation. Each point on a line divides the line into two rays; each line divides the plane into two half planes and so on.
3) Congruence. Along any ray one can mark a segment congruent to a given one; given any ray and a half plane adjacent to it, for any angle we can find a congruent angle lying in the half plane based on the given ray. The "side-angle-side" postulate for congruence of triangles.
4) Archimedean property. Given any pair of segments some multiple of the first segment is longer than the second one.
5) Parallel postulate. Given a point and a line not containing it there is a unique line through this point parallel to the given line.

**The study of real numbers required a whole new geometric insight due to Weierstrass, Dedekind, Cantor and others. In Euclid's time only Eudoxus and Archimedes came close to this insight.**

modern perspective would be that he had a 'model' for the universe.

An important mathematical feature of Euclid's theory is that rules of deduction are very strict; nothing — not even so-called common sense or intuition — can be taken for granted[1]. However, Euclid too fell into some traps set by common sense. One of the most (logically) circular parts of his theory is his use of the circle! A number of corrected or alternate approaches to Euclidean geometry exist today but none has the all encompassing breadth of his 'build–the–whole–thing–up–from–nothing' approach. The closest is Hilbert's approach (see the box for a quick summary).

[1] It can never be overemphasised that common sense has a love-hate relationship with science.

Nowadays the real number system that comes up in Euclidean measurement is often constructed algebraically (via the decimal numbers) and then *imposed* on geometry via the Ruler Placement Postulate. However, the idea (embodied in the Ruler Placement Postulate) that a line is the set of its points would have been totally unacceptable to the Greek mathematicians. In fact one of Euclid's attempts was to give a geometric construction of the number system. Each number $r$ is *represented* by a pair of line segments (the

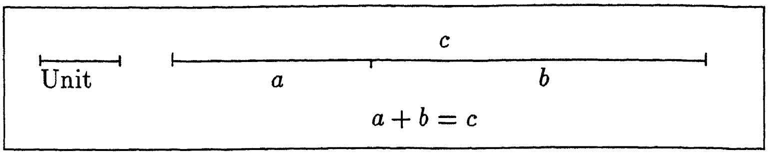


*Figure 1 Adding numbers.*

first gives the 'unit' of measurement and the second gives $r$ when measured in those units)[2]. Some simple constructions (see the *Figures 1,2,3*) show how we can add, multiply, divide and take square roots of numbers represented as above. (Exercise: Justify these constructions using Hilbert's axioms.)

[2] The fact that some line segments give rise to irrational numbers like $\sqrt{2}$ disturbed the common sense of Euclid and his contemporaries but was *not* in any way an inconsistency in the theory.

However, not every number of geometrical interest arises by successive application of the above constructions to the unit length. Two important unsolved problems of Euclid's time were (1) 'unrolling' the circle (2) 'doubling' the cube. In fact, as we now know from the theory of measure, 'most' real numbers *cannot* be constructed by means of straightedge (ruler) and compass; in Greek mathematics the only permissible entities were those constructed in this way. The study of real numbers required a whole new geometric insight due to Weierstrass, Dedekind, Cantor and others. In Euclid's time only Eudoxus and Archimedes came close to this insight[3].

[3] A relatively 'unknown Indian' by the name of Madhavacharya appears to have also come quite close.

## Co-ordinating the Plane/Brain[4]

[4] Unfortunately we mathematicians seem to fall into the 'gum-chewer' category; we can't chew gum (verbal) and walk in a straight line (spatial) at the same time!

> **Co-ordinates:** A pair (triple) of numbers uniquely identifying a point on the plane (in space).

By the time mathematics had wound its way via the Indian and Arabic traditions, the algebraic and arithmetic aspects had seen

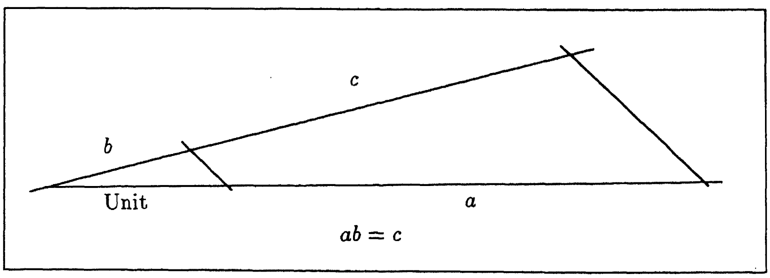


*Figure 2 Multiplying and dividing numbers.*

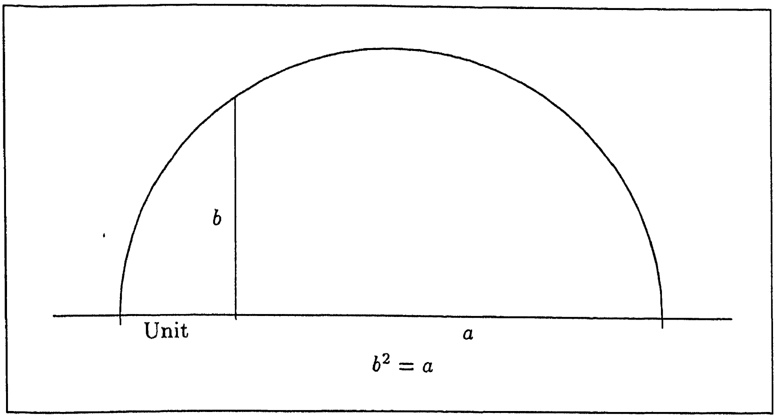


*Figure 3 Taking a square root.*

tremendous growth. With the use of negative numbers and (the all-important number) zero it became possible to talk of all the arithmetic operations on numbers. Decimal notation made arithmetic operations 'child's play'.

**Much of Euclidean geometry became absurdly simple if one used coordinates.**

In order to utilise this Descartes devised the following scheme. By fixing a point, the *origin*, on a line it becomes possible to talk of a directed distance as a positive or negative number depending on whether the end point is to one or the other side of the origin.

Similarly, he assigned a pair of numbers to every point of the Euclidean plane. First one chooses a pair of orthogonal lines called the *axes*. The intersection point of these lines is called the *origin*. The directed distance from the origin to the foot of the perpendicular from our given point to the first axis is called the *abscissa*; the directed distance from the origin to the foot of the perpendicular from our given point to the second axis is called the *ordinate*[5] *(Figure 4)*. (I have stated everything in words here to show

[5]So powerful is this pair of numbers working together with some (by now common) algebra and arithmetic that we use the term 'coordinated' for well-organised activity!

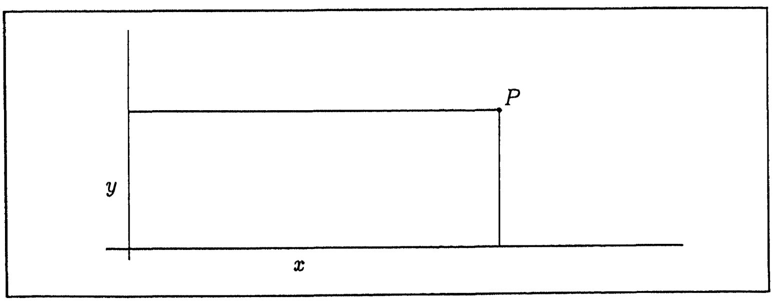


*Figure 4 The coordinate plane.*

**Like all good mathematics, the Cartesian coordinates also opened the door to newer geometrical ideas.**

how cumbersome this original — pre-algebraic — method of writing things was; this continued in Europe for quite some time in spite of the fact that the Indo-Arabic mathematicians had already introduced variables!)

On the one hand, it follows from Euclidean geometry that a point in the plane is uniquely determined by its Cartesian coordinates (Exercise: Prove this). On the other hand, much of Euclidean geometry became absurdly simple if one used coordinates (at least to those mathematicians who knew their arithmetic and algebra) — more importantly, the truth of various statements could be deduced by calculation (Exercise: Deduce all your favourite theorems and riders in Euclidean geometry using Cartesian coordinates). The tricky definition of a circle in Euclidean geometry gave way to the much clearer point of view that a circle is the locus specified by an equation $(x-a)^2 + (y-b)^2 = r^2$ where $(a,b)$ are the co-ordinates of the centre and $r$ the radius (Exercise: try to give *this* definition without using symbols!). While common-sense and intuition seem to take a back seat and algebraic manipulation comes to the fore, this is all to the good from the point of view of Euclid's deductive method.

This was not all. Like all good mathematics, the Cartesian coordinates also opened the door to newer geometrical ideas. Firstly, it became possible to talk about the locus associated with *any* (algebraic or functional) equation involving the two co-ordinates, e.g.

$$y^2 = x^3 - x$$

In other words, the study of plane curves was begun. Secondly, it was no longer necessary to "construct" all the geometrical figures that were studied (Exercise: Try to find a sensible way of tracing out the curve given by the equation above). The equations defined the figures and then the mathematician could "analyse" them. This led to the term *analytic* geometry of Descartes as opposed to the *synthetic* geometry of Euclid. Cartesian coordinates also opened

up the possibility of studying geometrical relations between non-spatial entities—one can draw a *graph* showing a geometrical relation between (say) the amount of gum chewed and the linear distance traversed[6]. Finally, a most important consequence was that one could study geometry in dimensions other than two and three. This idea flowered in the hands of Riemann.

[6] See earlier footnote 4 to see why this is important.

## Summary

Euclidean geometry in its original form has only a marginal role to play in modern mathematics. It is almost totally supplanted by Cartesian or analytic geometry. Why then do we still learn it? To give us a way of building our geometrical skills while we learn enough algebra and arithmetic to use coordinates. Moreover, it is probably not easy to *discover* new results in Euclidean geometry while thinking about it purely algebraically.

**Euclidean geometry in its original form has only a marginal role to play in modern mathematics.**

A number of questions remained unanswered even with the simplicity introduced by the coordinate approach. Will the circle be squared? Will parallel lines meet? Can curves be straightened? Wait for the exciting next instalment!

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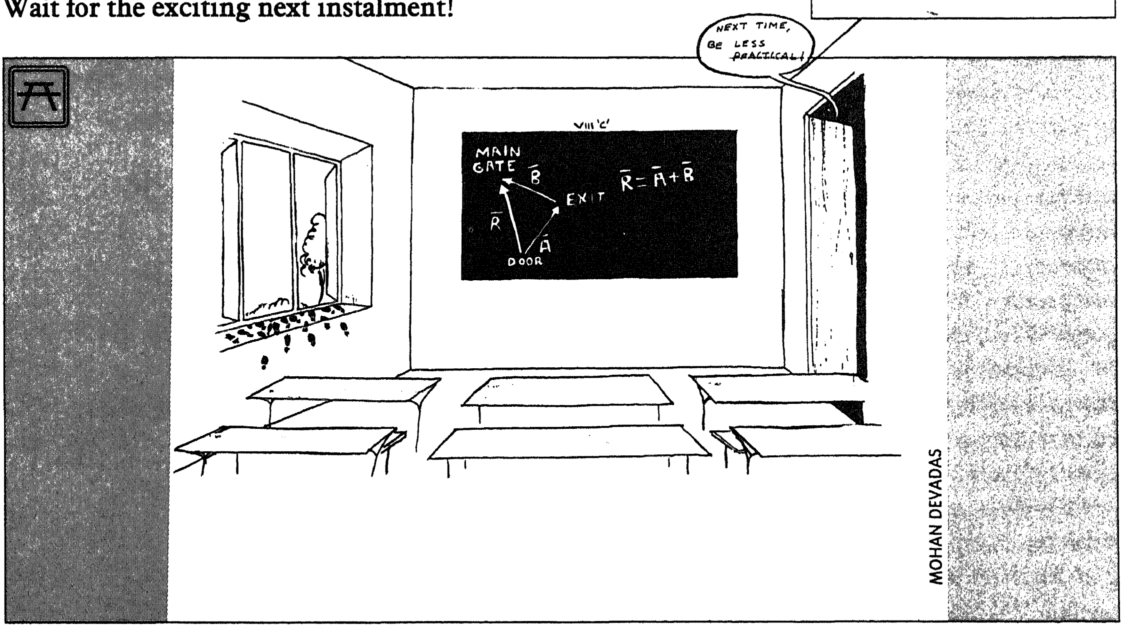


# Know Your Chromosomes

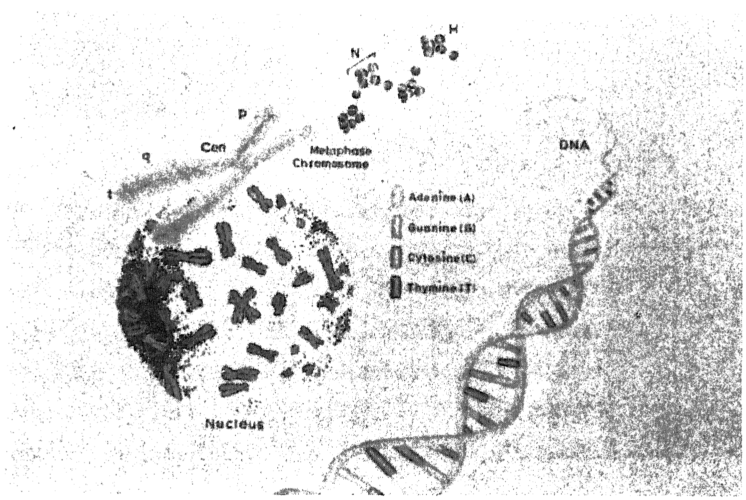
## 1. Nature's Way of Packing Genes

*Vani Brahmachari*

Vani Brahmachari is at the Developmental Biology and Genetics Department at Indian Institute of Science. She is interested in understanding factors other than DNA sequence *per se*, that seem to influence genetic inheritance. She utilizes human genetic disorders and genetically weird insect systems to understand this phenomenon.

**The study of cellular structures including chromosomes began as early as the 17th century. The organization of chromosomes, the structure and function of genes and the role of genetic mutations in diseases continue to be an area of intense scientific investigation.**

The size of an average human cell is 20-40 micrometers ($\mu$m) or microns ($\mu$). One micrometer is one millionth of a meter i.e., $10^{-6}$ meters). Deoxyribonucleic acid (DNA) the primary genetic material is located in the nucleus which is 8-20 $\mu$m . The DNA present in a single human cell if stretched out completely would have a length of about 1.8 meters (6 feet). That leaves us with the puzzle of how cells pack up 1.8 meters of DNA inside a tiny sac like the nucleus which is 0.000020 meters in diameter!! Nature has divided this DNA into 23 pieces and compacted them several fold to accommodate them in the cell nucleus. These pieces of DNA which are clusters of several genes are called linkages groups or chromosomes. Therefore chromosomes are nothing but long




SANJEEVA NAYAK

***Figure 1** From chromosome to DNA.. 't' is telomere; the end of a chromosome; 'q'- longarm; 'Cen' is centromere, which aids in segregating chromosomes to daughter cells during cell division; 'p'- short arm; 'N'- nucleosome, the unit of organization of chromosomes; 'H'- histones, which are proteins present in nucleosomes as octamers around which approximately 150 base pairs of DNA are wrapped. Adenine, Guanine, Cytosine and Thymine are nitrogen containing bases present in DNA.*

stretches of DNA compacted with the help of proteins. Under an electron microscope, chromatin appears as beads on a string: the string being DNA and the beads being the proteins (*Figure 1*).

In the 17th century, the structure of various cell types was analysed by light microscopy using specific dyes or stains. The cellular structures which readily took up the stain were the complexes of DNA and protein. Since the chemical nature of the darkly stained bodies was not known they were simply called *'chromatic elements'* — meaning coloured elements. The term chromosome was suggested by W Waldeyer in 1888. The number of chromosomes in a given species is characteristic of that species, and is maintained constant from one generation to the next. The chromosome numbers of some plant and animal species are listed in *Table 1*. Most organisms are 'diploid' meaning that they have two copies of each chromosome, one received from the father and the other from the mother. The sperm and the egg nuclei (which fuse during fertilization to form the zygote, that grows and develops into a complete organism) contain only a single copy of each chromosome. Therefore sperms and eggs are said to be 'haploid'. For instance, the diploid number of chromosomes in humans is 46 and therefore the haploid number is 23. The 46 chromosomes in each of our cells carry all the genetic information necessary to build a human being, in the form of genes made up of DNA.

**Table 1**
**Organism with its Chromosome number***

| Organism | Chromosome number |
|---|---|
| Man | 46 |
| Chimpanzee | 48 |
| Dog | 78 |
| Donkey | 62 |
| Mouse | 40 |
| Frog | 26 |
| Carp | 104 |
| Silk worm | 56 |
| Fruit fly (Drosophila) | 8 |
| Rice | 24 |
| Wheat | 42 |
| Tomato | 24 |
| Pea | 14 |

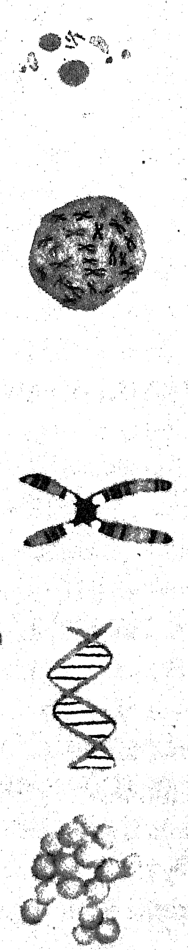
**The number indicates the diploid or 2n number of chromosomes. One chromosome of each pair is received from the mother and the other from the father.*

## Chromosomes: The Vehicles of Heredity

The number of chromsomes in humans has been known for only 39 years, while Mendel formulated his laws of inheritance 130 years ago and his work was rediscovered almost 95 years ago. We have been aware of the fact that children take after their parents and that certain diseases run in families. Plant breeding has been successfully practised by farmers who did not understand the genetic basis for crop improvement. Gregor Mendel, regarded as the father of genetics, saw a pattern in the inheritance of distinct characters in pea plants. The deliberate design of crosses between

**The number of chromosomes in a given species is characteristic of that species, and is maintained constant from one generation to the next.**

**The 46 chromosomes in each of our cells carry all the genetic information as genes necessary to build a human being.**



| | |
|---|---|
| $50 \times 10^{-6}$ m | Cell: is the building block of all plants and animals. There are about 100 trillion cells in the human body. |
| $20 \times 10^{-6}$ m | Cell nucleus : is present within each cell except red blood cells in humans and other mammals. This contains the genetic material, DNA organized as chromosomes. In each of our cells there is about 6 feet long DNA packed into 46 units called chromosomes. |
| $6 \times 10^{-6}$ m | Chromosome: Is a long thread of DNA wrapped around proteins. A specific block of DNA represents a gene. |
| $34 \times 10^{-9}$ m | Gene: is a unit of information usually containing information to make a protein. There are about 50,000-1,00,000 genes in each human cell. |
| $3\text{-}5 \times 10^{-9}$ | Proteins: are workhorses of the cell serving various purpose like transport of ions, antibodies to fight infections, and as catalysts in various biochemical reactions. |

SANJEEVA NAYAK

pea plants with distinct characters led him to formulate the laws of inheritance. The first application of Mendel's 'gene' concept to a human trait was by the physician A Garrod. He described the genetic disease alkaptonuria *(Box 2)* as an alteration in specific biochemical reactions leading to the excretion of homogentisic acid in urine. He introduced the concept of 'chemical individuality' and observed that an individual either does or does not excrete homogentisic acid; no patient exhibits intermediate states. In other words, the trait is a discrete one. This defect occurred in

**Alkaptonuria**

Amino acids are primarily used as building blocks for proteins and as precursors for other biomolecules like hormones, purines and pyrimidines. When an excess of protein is ingested, amino acids derived from protein degradation are used as a source of energy by a process called oxidative degradation.

In one such pathway phenylalanine is converted into acetoacetyl COA through a series of enzymatic reactions.

One of the steps in this pathway is the conversion of homogentisic acid, an intermediate in this pathway, to 4-malelyl acetoacetic acid by an enzyme called homogentisic acid 1,2-dioxygenase.

If an individual has a defect in the gene coding for this dioxygenase it will lead to the production of a non-functional enzyme. This in turn results in the accumulation of homogentisic acid and its excretion in urine. This condition is described as alkaptonuria.

Defects at other steps in this pathway lead to genetic disorders like phenylketonuria, tyrosinemia and albinism.

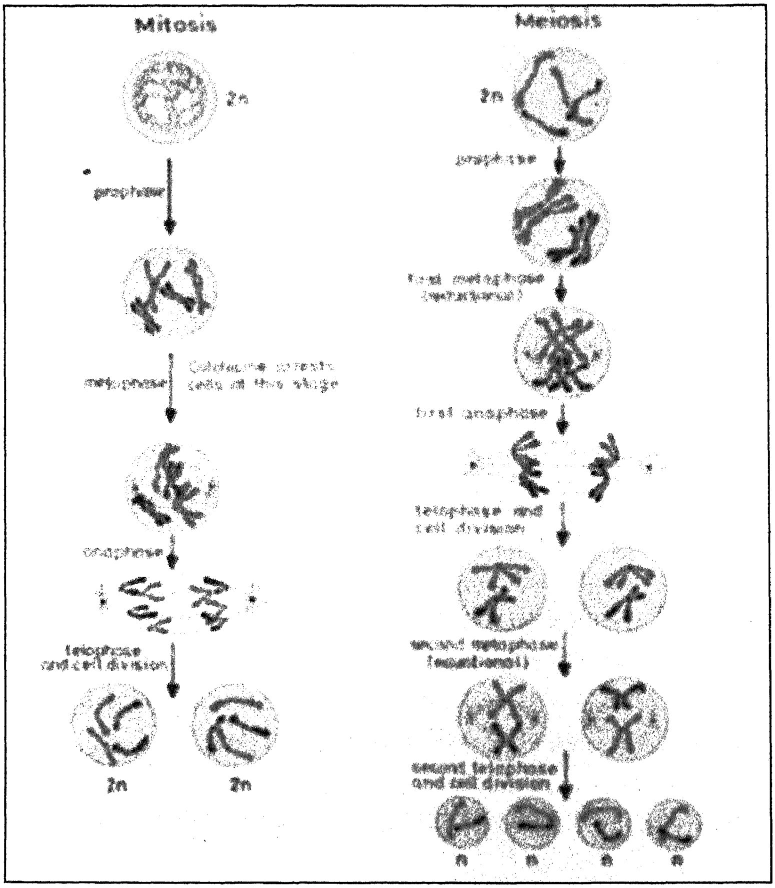
**The first application of Mendel's 'gene' concept to a human trait was by the physician A Garrod. He described the genetic disease alkaptonuria as an alteration in specific biochemical reactions leading to the excretion of homogentisic acid in urine.**

children of several first-cousin marriages but not all marriages between relatives resulted in children with the disorder. He reasoned that there may be some peculiarity in the parents of children who inherited the disease. Garrod recognised that Mendel's laws of heredity could provide a reasonable basis for the phenomenon. In 1908, he published his monograph on inborn errors of metabolism which was a reflection of his great insight into the role of genetics in human physiology. As is often the case in the history of science, Garrod's contributions to human genetics remained unappreciated during his lifetime.

Before the rediscovery of Mendel's work in 1900, the process of

**It was found that what was described as Mongolism and later as Down's Syndrome was actually the presence of three copies of chromosome 21 instead of the normal two.**

cell division, meiosis and mitosis (*Figure 2*) had been analysed and the chromosomes were identified as entities that are evenly distributed between daughter cells during cell division. The similarity between Mendelian segregation and chromosomal distribution during meiosis was correlated and chromosomes were identified as bearers of genetic information. Soon after the rediscovery of Mendel's work (1902 and 1903) chromosomes were recognised as units of heredity by different scientists independently. Thus the discipline of cytogenetics developed with experiments in plants like Lilium and insects like the fruit fly, Drosophila. Although it was only in 1956 that the correct number of chromosomes in humans was established, the Mendelian mode of inheritance was illustrated by the inheritance of the ABO blood groups by Landsteiner in 1900 and by two German scientists in 1911.



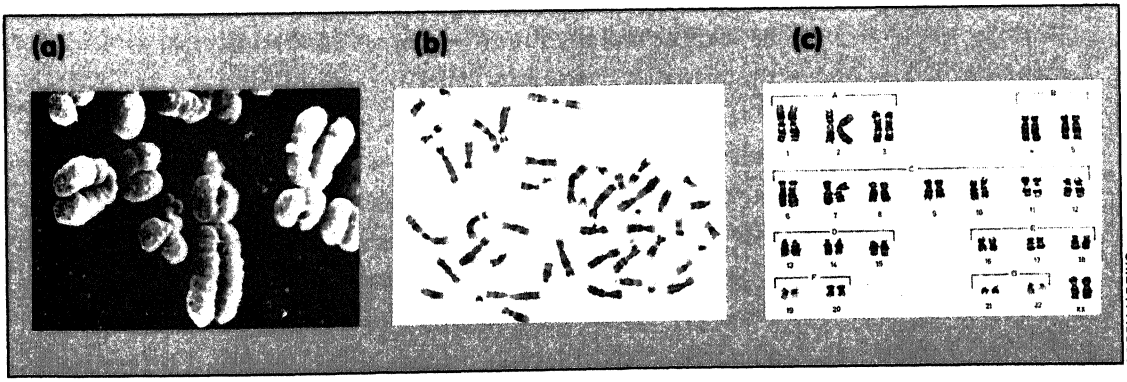

SANJEEVA NAYAK

***Figure 2 Diagrammatic representation of steps in nuclear division during cell division. 2n and n represent the diploid and haploid state of the nuclei. In the given example 2n = 4. Meiosis takes place during production of the egg and the sperm.***

In the summer of 1955 Albert Levan, a Swedish cytogeneticist visited T C Hsu, who had developed a modified method for chromosome preparation and learned the method of preparing chromosomes from human cells. Later, Albert Levan with Joe Hin Tijo discovered that by adding colchicine, an alkaloid derived from plants, the highly condensed state of metaphase chromosomes can be blocked from proceeding further (*Figure 3*). The tissue with which they worked was human embryonic liver. Out of the 261 metaphase cells they observed most had 46 chromosomes. To this day a large number of metaphases are observed by cytogeneticists before reporting the diagnosis of the chromosomal status of a patient. Following this discovery it was found that what was described as Mongolism and later as Down's Syndrome was actually the presence of three copies of chromosome 21 in the patients instead of the normal two. Anomalies in chromosome number, in particular that of the sex chromosomes, were also reported in patients who had abnormal sexual development. All these were substantiated after the development of new meth ds for the analysis of human chromosomes. From this perspective the revolution in the study of chromosomes referred to as cytogenetics seems to have arisen from methodological improvements rather than the development of a new concept. The advantage was that inferences drawn from previous observations did not lose their value but got further supplemented and reinforced. Thus human cytogenetics attained a new dimension. In the following years it was discovered that several human hereditary disorders are due to chromosomal defects.

**Several human heredity disorders are due to chromosomal defects.**

***Figure 3** Chromosomes as visualised by different methods (a) scanning electron micrograph of human chromosomes. (b) a metaphase spread prepared from lymphocytes (WBC) at metaphase stage of cell division. The banded pattern is due to differential giemsa staining. (c) a metaphase spread photographed under the microscope; individual chromosomes are cut up and arranged in order after comparison with a standard banding pattern. This is called a* **karyotype.** *This karyotype (provided by Dr Sridevi Hegde, St John's Medical College, Bangalore) is that of a woman.*




SRIDEVI HEGDE

**The procedure of preparing a picture of chromosomes of an individual is called 'karyotyping'.**

## Chromosomal Nomenclature

The chromosome number in each cell was established but how was the nomenclature arrived at? In 1968 it was realised that certain dyes stain chromosomes in a non-uniform fashion giving rise to lighter regions and darkly stained regions. This produces the pattern shown in *Figures 3 b,c*. There is also a variation in the length of chromosomes and in the position of the centromere which helps in the segregation of chromosomes to daughter cells, during cell division. Chromosomes are ordered and numbered by two different conventions. Based on their length they are ordered 1 to 23. In the other system 23 pairs are distributed into groups A to G based on their length and the centromere position. Both systems are indicated in *Figure 3c*, the pairs from 1 to 22 are called autosomes and the 23rd pair is called the sex chromosome, typically denoted by the letter X and Y. A female has 22 pairs of autosomes and two X-chromosomes (44XX), whereas a male has 22 pairs of autosomes, an X-chromosome and a Y-chromosome (44XY). Now you can appreciate the fact that by a chromosomal analysis of an individual one can identify any change in number, length or staining pattern of chromosomes. This procedure of preparing a picture of chromosomes of an individual is called 'karyotyping'.

## From Chromosome to Genes

The total amount of DNA in 23 chromosomes is estimated to be three billion ($3 \times 10^9$) base pairs. Base pair means a pair consisting of adenine and thymine (A-T) or guanine and cytosine (G-C) — the nitrogen containing bases in the building blocks of DNA. Therefore the total amount of DNA in our cell is six billion base pairs (in 46 chromosomes). The identification of any change in the number of chromosomes is relatively easy, but any change or loss of only one or a few genes from a chromosome will not lead to a change in the length that is detectable under a microscope normally used for karyotyping. For instance, to find the cause of a hereditary disorder like haemophilia (a genetic disorder result-

ing in defective blood clotting), the challenge before the scientists was to find a single base pair change out of six billion base pairs. It sounds almost impossible. But scientists have worked out a way of narrowing down the region of the defect step by step. Some of the steps in this process are as follows: (a) to derive the pattern of inheritance (autosomal or sex linked) by family history or pedigree analysis; (b) to find the linkage group or the chromosome on which the gene is likely to be located; (c) to find neighbouring markers or genes and (d) finally to find the defective gene itself. With the advent of modern methods in biology, the order in which the steps are taken towards identifying a gene related to a trait can be different in different cases. But whatever the starting point one would like to derive all the information outlined in (a)-(d) to help in diagnosis, treatment or prevention of a genetic disorder or in finding a gene.

**To find the cause of a hereditary disorder like haemophilia the challenge before the scientists was to find a single base pair change out of six billion base pairs.**

The total number of genes known in humans to date is reaching 6,000. But this is only about 6 to 12% of the total number of genes estimated to be present in humans. Moreover each gene does not function in isolation. It is like the words in a sentence; with different meanings in different contexts. Similarly, a gene can be a part of different complex processes contributing to different end products. Most often it is the defect in a gene which leads to the understanding of its normal function. In future articles, we will learn more about the structure and function of individual chromosomes along with the processes used to study them.

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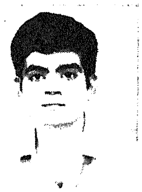
# Know Your Personal Computer

## 1. Introduction to Computers

*S K Ghoshal*



**Siddhartha Kumar Ghoshal works with whatever goes inside parallel computers. That includes hardware, system software, algorithms and applications. From his early childhood he has designed and built electronic gadgets. One of the most recent ones among them is a sixteen processor parallel computer with IBM PC motherboards.**

**This article describes in brief the basics of the organization of the control and processing unit, memory subsystem and peripherals of a computer.**

### Introduction

Computers are built using semiconductors and other electronic parts, magnetic media and electromechanical devices. Collectively these are called the *hardware* of the computer. Their organization is subdivided into Control and Processing Unit (CPU), Memory subsystems and peripherals. They come in all sizes and capabilities, ranging from supercomputers to pen-tops, but there is a basic unity in their organization. We will first discuss the organization of computers and follow with a discussion on peripherals and software.

### Computation and Memory

Just as humans use a base-10 arithmetic system because they have ten fingers on their two hands, computers use a base-2 arithmetic as digital hardware computes and stores information most reliably in one of two stable states, called OFF and ON. Alternatively they are called 0 and 1. *Bit* is an abbreviation of binary digit.

Using patterns of bits, computers store integers, rational numbers called *floating point numbers* which approximate real numbers, characters and many other data types.

***Figure 1 Computer-memory subsystem.***

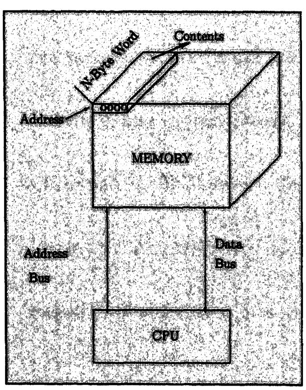



*Figure 1* is a block diagram of a computer. It consist of a CPU and memory.

### About the series "Know Your Personal Computer"

The advent of personal computers in the early 1980s revolutionized the applications of computers. Computers which were expensive and somewhat daunting to the common man suddenly became affordable to many small organizations and individuals. An early decision by IBM (International Business Machines Corporation) to publicize the internal hardware structure and interface details enabled many manufacturers to design 'IBM clones' and price them competitively. Concurrently software companies, particularly Microsoft, designed an operating system called MS-DOS (Microsoft Disk Operating System) which allowed a novice to start using the computer. A host of compilers for popular programming languages (C, FORTRAN, PASCAL, COBOL etc.) appeared. Application programs for word processing, database design, accounting and numerous other areas were developed. These developments are of particular significance to India as computers became affordable to many colleges, schools and individuals. Almost all colleges and many schools now have computer centres with numerous personal computers. Students routinely use them to write programs. As a user one is usually curious to know what is 'inside the personal computer' and learn details not usually found in text books. The intention of this series is to explain in some detail the hardware and software of personal computers. It will include articles on the CPU system, memory system, peripheral systems, PC interfacing, basic input-output system, PC operating systems, PC networking, multimedia and some recent developments related to PCs.

The topics are chosen such that a science graduate will have a reasonably good knowledge of computer basics, applications of computers and future trends if she or he diligently reads the articles in the series. It will assist the teacher in supplementing information found in text books with issues of practical consequence in using personal computers and may even be useful in troubleshooting personal computers.

The series is written by S K Ghoshal who has many years of experience in designing systems using PCs. Readers are welcome to send suggestions on the articles and queries about personal computers.

*V Rajaraman*

A CPU can operate on these data types (called *operands*) and produce results specific to these types. The type of the operation performed is called the *op-code*. An op-code combined together with the addresses of the operand is called an *instruction*. An instruction is also represented as a bit pattern.

**Just as humans use a base-10 arithmetic system because they have ten fingers, computers use a base-2 arithmetic.**

A collection of instructions is called a computer program, or code. They are kept in memory, which is a collection of memory cells

organized in a highly regular fashion. Eight bits are grouped together and called a *byte*. Each byte-wide memory cell has a unique address and its contents can be accessed by referring to it by the address. The memory is connected to the CPU, using a large number of data and address lines, called a *bus*. There is an *address bus* which is unidirectional and conveys the addresses generated by the CPU to the memory. There is also a bidirectional *data bus* which allows memory to exchange data with the CPU.

The width of the data bus is usually a multiple of eight. Memory is thus often organized in bytes as a whole. Each byte has a unique address. A byte is the minimum unit of information exchanged between the CPU and the memory. Each data type needs an integral number of bytes to be represented.

When data is brought inside the CPU for manipulation, it is kept in memory cells which are located in the CPU and called *registers*. Registers are also as wide as the integral multiple of bytes.

Each instruction also needs an integral number of bytes to be stored. The CPU fetches, decodes and executes them one by one. The CPU has an internal register called the *program counter (PC)* to index into the code memory and point to the next instruction to be executed. There is no way to distinguish between an instruction and a data-type and this fundamental limitation of today's computer organisation delays the development of correct programs.

The main memory of a computer can be read and written and data which is to be manipulated is stored in it. The code that is translated from highlevel language is also kept in the main memory. Code memory should not be over written although some programs called *self modifying code* do this.

When digital hardware is switched on, it is uninitialized. Each one-bit memory cell of the system can be in a state 0 or 1, which is decided randomly as it depends on so many physical parameters

**Self Modifying Code**

This idea of interchangeability of instruction and data was one of the most important ideas of von Neumann. In the early days of computers this allowed one to write self modifying programs. So the same instruction could be executed repeatedly each time modifying its bit pattern to give it a different meaning or to make it access operands from different memory locations. In those days memory was scarce. So programs had to manage with tiny amounts of memory (compared to today's standards) and do a lot of work by the same standards. Thus, without a self-modifying code many programs which later became the first working prototype of the many application programs of today, would never have been written. However it is difficult to make self modifying programs work correctly and even more difficult to document them. So their use is discouraged.

beyond the analysis and control of the system designer. Thus before hardware can be used, it must be initialized.

That is done by executing the code from a *read only memory* (ROM) which cannot be altered by the CPU and which retains the information even when the computer is switched off. ROMs also contain many data objects that are needed to initialize the computer before it can be used. Programs and data stored in a ROM are collectively referred to as the *firmware* of the computer. In order to make the CPU begin its execution by fetching code from the ROM, a signal called RESET is applied to the CPU from outside. In most systems it is generated when the system is switched on. Optionally there is a reset button.

Main memory is made of two types of memory cells: static RAM (SRAM) and dynamic RAM (DRAM). Static RAMs consume more power per bit but are faster.

A given computer system has both of the above types of memory. A small amount of SRAM and a large amount of DRAM comprise the main memory system. Programs display a phenomenon called coherence which can be used effectively to design the memory systems of computers. There are two types of coherence:

- *Temporal Coherence* which means that if a given memory location is accessed now, there is a fair chance that it will be accessed soon again.
- *Spatial Coherence* which means that if a given memory location is accessed, it may well be that its neighboring locations will be accessed next.

Thus it helps to keep frequently accessed blocks of memory in fast SRAMs, which are backed up by slower but larger DRAMs. This principle is called *caching*. The smaller, faster memory at the higher level (i.e., closer to the CPU) is called *cache* memory

**Locality of Reference**

There is a phenomenon called locality of reference which programs display when they are executed. In fact 90% of the time they access 10% of the total memory locations they use if one takes an average over a large number of programs. Both temporal and spatial coherence are responsible for this. Temporal coherence occurs because programs often execute in tight loops, waiting for an iteration to converge or for some other event to take place. Spatial coherence arises because programmers often place data objects of the same type (for example the elements of a matrix) in consecutive memory addresses and perform similar transformations on them, one by one.

**The memory is connected to the CPU, using a large number of data and address lines, called a bus.**

**What is a 'Cache'?**

The dictionary meaning for cache is "a hiding place for food and stores left behind (e.g. by explorers) for future use". In computers however, it denotes a small but fast memory which acts as a temporary storage or as a buffer between two levels of memory.

whereas the larger and slower memory at the lower level, further away from the CPU is called *main memory.*

Note that this usage is relative as there are usually many levels in a hierarchical organization of a memory system and what is cache memory at a given level may itself be main memory at the next upper level. Caching is used at all levels in a memory subsystem design. The aim is to provide a memory that appears as fast as the cells in the highest level and as large as the capacity of the lowest level. For programs that are coherent, this aim is realized to a large extent. Between the SRAM and DRAMs of the memory system, the caching functions are performed *in hardware,* that is, by designing and physically implementing digital circuits using semiconductor integrated circuits. These circuits are called *cache controllers.*

Caching is *transparent* to the program that is running on the computer or the programmer who wrote the program. The program does not need to be written in a special way to accommodate caching. Nor does the programmer even have to be aware of it. Whether at a given point of time during the execution of the program (called *runtime*) a given data object or instruction is there in the main memory or the cache memory is decided based on the behaviour of the program in the immediate past and other ground realities prevailing at that instant.

**Caching is used at all levels in a memory subsystem design. The aim is to provide a memory that appears as fast as the cells in the highest level and as large as the capacity of the lowest level.**

## Secondary Memory

Main memory is too small to hold all the data and code that is required. So *secondary memory,* which is magnetic in nature, is used to supplement main memory. Secondary memory is slower, but is cheaper per byte and is much larger in size, than the main memory. It can be used in two ways:

- *Virtual memory* where the magnetic disk holds the code and data objects which are not needed at the very moment of runtime. However, the objects are placed in such an address space that they can be addressed by the CPU (this address

is called the *virtual address space* because it need not s be populated by *physical* memory) directly at any time. are kept in disks and loaded into the main memory when d. To make room for them, some other blocks of ry which have not been used for sometime are stored in isk.

*al storage* where objects are removed from the CPUs ss space. They are brought back by a time consuming ss requiring human intervention.

ementing virtual memory, random access magnetic stor- a, typically disks, are employed. This is because the CPU ntially require any item in its virtual address space at any The physical location of the object referred in the virtual space should not affect its access time. So magnetic devices such as floppy and hard disks, whose arms can desired track are used to implement virtual memory. ices are called *swap devices* because they swap data objects pages to and from the main memory. Of course floppies slower as swap devices and in most cases it is impractical m due to their small storage capacities. In a hard disk, the material is coated on mechanically inflexible (hence the ircular aluminum platters which rotate at very high nd the read/write heads float above them at a very small Hard disks can record data at very high densities and em very fast. In floppy disks, a flexible substrate (hence e) coated with a ferromagnetic material is squeezed by a eads. Floppy disks are cheap and can be removed from the

ival storage and retrieval of data and programs, one can use al storage devices. An example is magnetic tapes. They can ed only from the beginning to the end and an object which deep inside the medium can be accessed only after all other receding it have been accessed and/or skipped. For backing estoring contents of memory, this is adequate. Tapes cost e per bit of storage. Their capacities too are enormous.

**What is a 'Transparent Mechanism'?**

We call something transparent, if light passes through it. Glass is transparent. So one does not see glass itself. One sees what is behind the glass. If the means of making something happen is not visible, that mechanism is called *transparent* in computer parlance.

**In a hard disk, the magnetic material is coated on mechanically inflexible (hence the name) circular aluminum platters which rotate at very high speeds and the read/write heads float above them at a very small height. Hard disks can record data at very high densities and access them very fast.**

**There is no way to distinguish between an instruction and a data-type and this fundamental limitation of today's computer organisation delays the development of correct programs.**

Caching is employed between the swap device and main memory. Frequently referred objects are retained in the main memory. Objects not in use are put back into the swap device. This is one of the memory management chores that an operating system of the computer performs routinely. Users and developers of computer programs need not be aware of these functions.

Thus objects go up and down the levels of memory hierarchy (see *Figure 2*). An object which is frequently used will eventually find itself in the CPU registers provided it is small enough to fit there. On the other hand, objects not in use will go further and further away from CPU until they are backed up in a tape and removed from the computing system.

## Peripherals

These are attached to the computers. They extend the computers' capabilities to function like printing on paper, exchanging information with other computers, accepting input from human beings, displaying text or graphic images and the like. Peripherals, by themselves cannot do anything. They always need to be

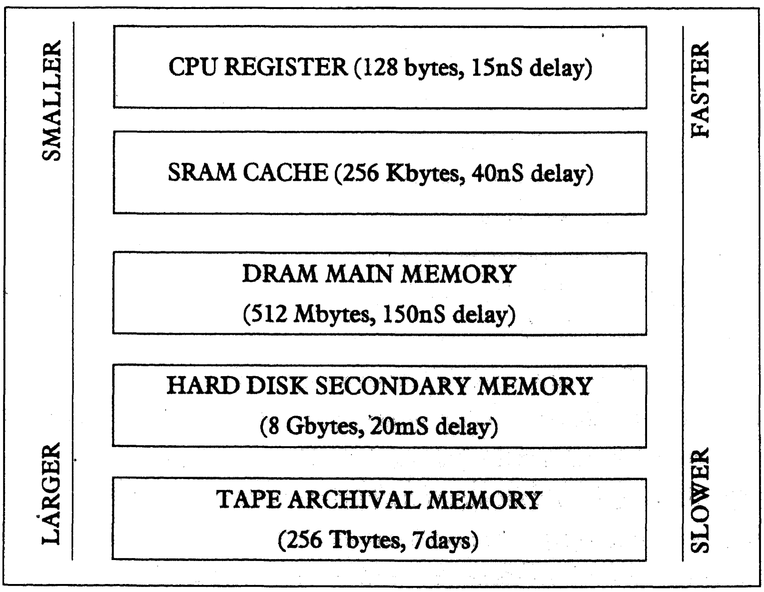



***Figure 2** Levels of memory hierarchy, typical site and speed at each level is given as of 1995. These typical numbers change every year.*

a computer, usually referred to as the *host computer*. too can have their own memory, but that is beyond the ess space of the host computer. Often they have their ı CPUs which perform special functions within that levice. In such cases, the microcontroller chip con- CPU is called an *embedded controller*.

**Peripherals extend the computers' capabilities to function: they help in printing on paper, exchanging information with other computers, accepting input from human beings and displaying text or graphic images.**

rograms that run on a computer is collectively called . There are two types of software:

*oftware* which manage resources like the CPU and the emory, extend the capabilities of the hardware and e help users and application programs use the computer. *ion software* which run on the computer and have some

of system software are operating systems, different d high-level language compilers.

many types of applications of computers. Numeric tabase and symbolic computing applications are some ertain computers are specially suited for certain appli- d they keep evolving towards performing better and usable in these applications until they end up being controllers in a special purpose equipment. Others are built, sold and used as "general purpose computers" run applications from a wide range of fields but do not ptimally in any of these roles. We will focus our atten- ure articles on general purpose computers.

arn more about CPUs, memory subsystems, system ıd application software in the subsequent articles with erence to personal computers. If you have any reactions cle or the subsequent ones, please write to me.

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# Learning Organic Chemistry Through Natural Products

## 1. Natural Products - A Kaleidoscopic View

*N R Krishnaswamy*

N R Krishnaswamy was initiated into the world of natural products by T R Seshadri at University of Delhi and has carried on the glorious traditions of his mentor. He has taught at Bangalore University, Calicut University and Sri Sathya Sai Institute of Higher Learning. Generations of students would vouch for the fact that he has the uncanny ability to present the chemistry of natural products logically and with feeling.

**A naturally occurring organic compound has been chosen to illustrate (a) structure determination by chemical and spectroscopic methods, and (b) synthesis and chemical transformations.**

Organic chemists isolate or synthesize new compounds all the time. How does one identify their structures? Some may answer — "X-ray"! However, X-ray diffraction can be used to determine structures only for compounds which form single crystals. For the vast majority of organic compounds, structure elucidation is carried out by a combination of chemical transformations and spectroscopic analyses. In this article we discuss the general approach that is followed using a natural product as an example.

In order to keep the focus on chemistry, we defer giving its trivial name and plant source till the end of the discussion. An additional bonus of such an approach is that the student logically deduces the structure from the given set of data and does not merely recall the structure from memory. Further, wherever possible we look at a problem from different angles thus covering a wider ground.

As our first example we choose a molecule, designated as **A**. We describe two different analytical approaches and a synthetic approach for elucidating and confirming its structure. The classical method which has developed over the years from a large volume of experimental work will be described first.

The first step in structure elucidation is the determination of the correct molecular formula, which for compound **A** is $C_{10}H_{18}O$.[1]

[1] Empirical formula is determined from combustion analysis.

[2] Thin layer chromatography (TLC) is an analytical tool to separate compounds based on their differential interactions with a stationary phase and a moving solvent. A species with a greater relative affinity for the solvent moves faster (higher $R_f$ value) on a TLC plate.

**The Series on "Learning Organic Chemistry Through Natural Products"**

Nature is a remarkable and excellent teacher. For effective learning, one needs a suitable language and the language of organic chemistry appears ideal for understanding nature at the molecular level.

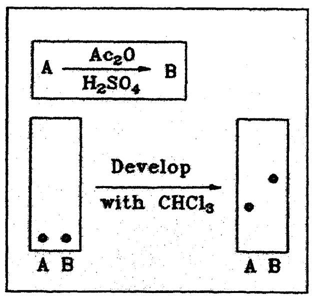
The molecules of nature, the small and the big, individually and collectively give form, shape and substance to the living organisms in which they occur. The key to their biological functions is their chemistry which in turn is intimately associated with their structures. Therefore, the first step in the study of biomolecules is to find out their structures and stereochemistry. Next, the reaction profiles of a molecule need to be established as they enable us to understand the biological activity. An organic chemist does not just stop at that, but goes further by creating it ingeniously in the laboratory using tools of her own. This *synthesis* is an integral part of organic chemical research and the inspiration for it is provided by nature. Thus, the chemistry of natural products forms a wide canvas portraying every kind of organic chemical activity and going beyond. It acts as a bridge for transferring principles and concepts of chemistry to the biosciences thus providing a molecular basis for biological phenomena.

How does effectively learns a subject of such vast dimensions within a short time is an intriguing question. At present organic chemistry is taught in a narrative form and the student is compelled to memorise a vast amount of descriptive data and a wide variety of apparently unconnected structures. It is therefore not surprising that the subject is not favoured by serious students seeking intellectual contents. This is unfortunate since half a dozen carefully chosen natural products can take a student to every nook and corner of organic chemistry, and illustrate and highlight important guiding principles of the subject. This can be done by removing artificial barriers which at present divide natural products into various structural categories. *Therefore, when one shifts the focus from the gross skeletal structure to the interior electronic configuration, the need for classification based on structural types loses importance, and the emphasis shifts to fundamental chemical principles which are few and unifying.

*N R Krishnaswamy*

*A structure is like a skeleton. What gives it 'life', like flesh and blood, are the bonding and the non-bonding electrons incorporated in the structure.

What is the next step? The functional groups are to be determined now. The nature of the oxygen functionality is shown by a simple reaction which can even be demonstrated on a thin layer chromatogram.[2] The adjacent picture shows the TLC behaviour of **A**, and the product obtained after treatment with acetic anhydride or sulphuric acid.




From the chromatogram it can be inferred that **A** has a hydroxyl

group since it undergoes acetylation. **B** moves higher with the solvent (higher $R_f$ value) indicating its weaker interaction with the silica surface.

**A** can be oxidised with $MnO_2$ to yield **C** ($C_{10}H_{16}O$) which forms an *orange-red* derivative with 2,4-dinitrophenylhydrazine (DNP).[3] These observations suggest that **C** is an $\alpha$, $\beta$-unsaturated aldehyde or ketone. Compound **C** does not answer the iodoform test ($I_2/OH^-$), but reduces Tollen's reagent, suggesting that it is not a methyl ketone, but an aldehyde.

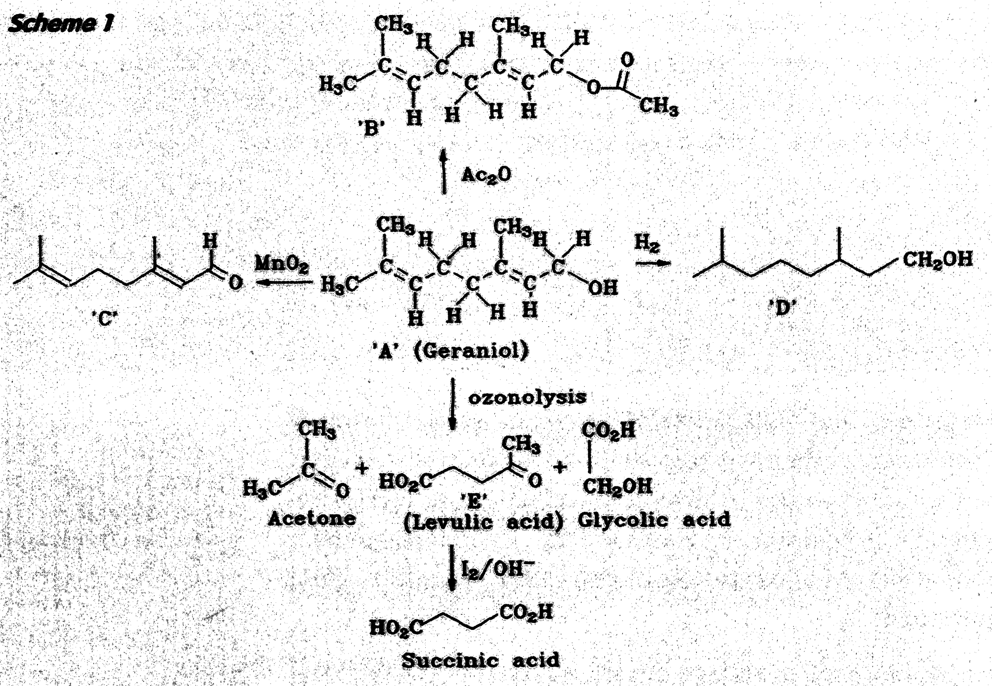
[3] (a) $MnO_2$ is a specific oxidant for allylic and benzylic alcohols, (b) DNP derivatives of saturated carbonyl compounds are *pale yellow*, whereas highly conjugated compounds like benzophenone give *brick-red* products with DNP.

**A** on catalytic hydrogenation gives a *tetrahydro* derivative **D** ($C_{10}H_{22}O$), showing thereby that it has two double bonds. The molecular formula of **D** also shows that it is a saturated alkanol. *Therefore,* **A** *is a doubly unsaturated, acyclic allylic primary alcohol.*

[4] Ozonolysis cleaves a double bond to produce two carbonyl compounds. Oxidative workup converts an aldehyde to the carboxylic acid. Ketones are unaffected.

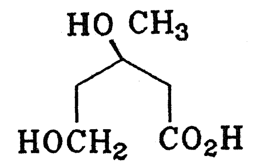
Ozonolysis of **A** followed by oxidative workup[4] yields one molecule each of acetone, glycolic acid, and a keto carboxylic acid **E**

*Scheme 1*



($C_5H_8O_2$). Compound **E** on treatment with $I_2/OH^-$ gives succinic acid. These reactions are shown in *Scheme 1*. The keto acid **E** could therefore be identified as levulic acid. The structure of **A** can thus be logically derived as shown in the scheme. This compound is *Geraniol* which is a component of several essential oils including the oil of Geranium.[5]

[5] Biosynthetically, geraniol is the first member of the terpenoid family arising from two units of mevalonic acid.



Mevalonic Acid

We will now describe an alternative approach based on modern instrumental methods for finding out the structure of geraniol.[6] Among the advantages of this approach are the fact that unlike the classical chemical method, it is by and large non-destructive and can be operated on micro quantities of the compound. But the data obtained from the two approaches are not the same and, taken together, they give a more complete picture of the molecule than that available from either set of data. Therefore the best approach to structure determination would be a judicious combination of spectroscopic methods with a few selected chemical transformations.

[6] The following five paragraphs contain advanced material, and will require some knowledge of spectroscopy.

In order to determine the *chromophoric* ('colour producing') groups a UV/ Vis spectrum can be taken.[7] The UV spectrum of a methanolic solution of **A** shows an intense absorption at about 205 nm. In the UV spectrum of **C**, there are two absorption maxima at 205 and 232 nm. The inferences are: **A** has two similar, if not identical chromophores. The position of the absorption maxima indicates that they are trisubstituted ethylenic double bonds. In **C**, one of these chromophores is retained while the other, responsible for the maximum at 232 nm, is an $\alpha, \beta$-unsaturated aldehyde.

[7] UltraViolet absorption arises due to *electronic excitation* of functional groups called *chromophores*. For example, in an olefin it is an electronic transition from the $\pi$-orbital to the $\pi*$-orbital.

The IR spectra of **A** and **C** provide important information.[8] The spectrum of **A** has a broad band at 3350 $cm^{-1}$ which is absent in the spectrum of **C**. This band is due to a hydroxyl group. The spectra of both **A** and **C** have bands at 3040 (=C–H), 2920, 2860 and 1350 ($CH_2$ and $CH_3$ groups) $cm^{-1}$. These bands show that **A** and **C** possess an aliphatic skeletal framework with one or more double bonds. The most prominent absorption band in the spectrum of **C** is seen at 1680 $cm^{-1}$ which is absent in the spectrum of **A**. This

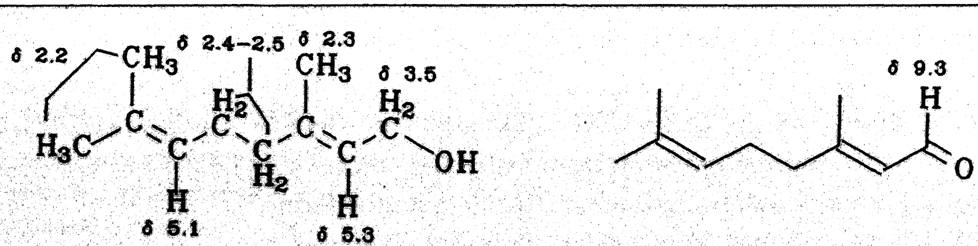
[8] InfraRed spectroscopy is used to characterize vibrational (stretching, bending etc) energy levels of molecules. Groups such as O–H, C–H, C=O can be easily identified from IR spectra. The nature of the C=O (e.g., acid chloride, amide, ester etc.) can also be determined.

[9] Nuclear magnetic resonance is a technique in which the energy levels of magnetic nuclei can be observed by looking at the absorption (resonance) of electromagnetic radiation in the presence of an external magnetic field. Hydrogen is one such nucleus, and the chemical environment of the hydrogen affects the resonance frequency making it a valuable analytical tool for chemists. This resonance frequency, converted to a parts per million dimensionless scale, is reported as the $\delta$ value. Typically, higher the partial positive charge on a hydrogen atom, higher is its $\delta$ value.

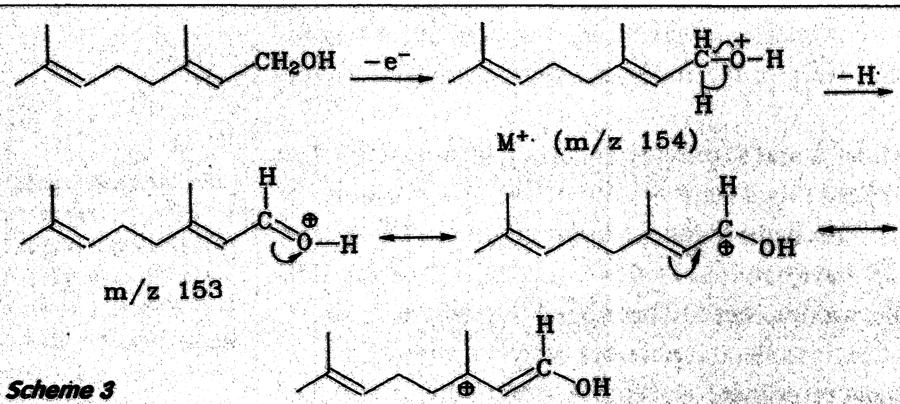
band is due to the $\alpha, \beta$-unsaturated carbonyl group. The presence of the CHO group in **C** is also indicated by a band at 2800 $cm^{-1}$.

The $^1$H-NMR spectra of **A** and **C** provide the most compelling evidence for their structures.[9] The spectrum of **A** has signals at $\delta$2.2 (s, 6H), 2.3 (s, 3H), 2.4-2.5 (m, 4H), 3.5 (d, 2H), 5.1 (t, 1H) and 5.3 (t, 1H). These data show the presence of three methyl groups on $sp^2$ carbons, two olefinic hydrogens (each on a carbon atom next to a $CH_2$ group as the signals appear as triplets), and a $CH_2$–$CH_2$ unit. The signal at $\delta$3.5 is due to the $-CH_2OH$ end group next to an $sp^2$ carbon. This signal shifts to $\delta$4.5 upon acetylation of **A**. From these data it is possible to deduce the structure of **A** as shown in *Scheme 2*.

In the NMR spectrum of **C**, the two proton signal at $\delta$3.5 is missing, and instead, there is a one proton doublet at $\delta$9.3, due to the aldehydic proton.




*Scheme 2*




*Scheme 3*

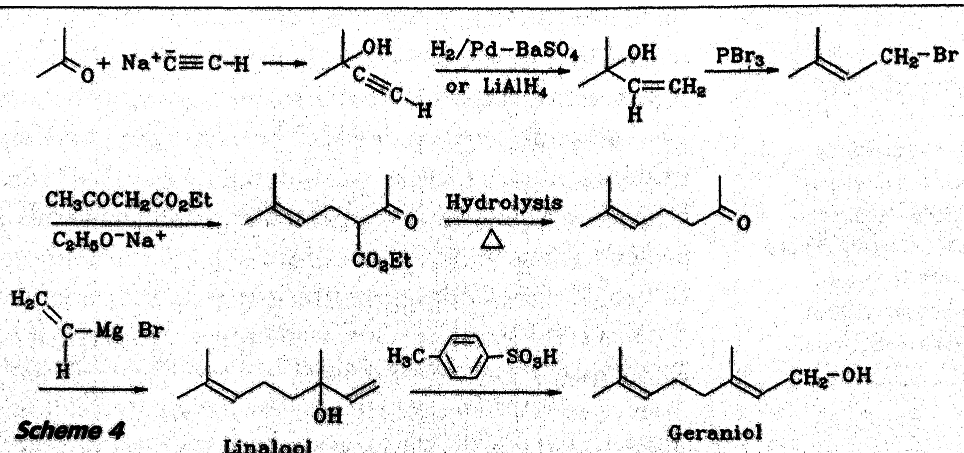
*Scheme 3* gives the mass spectral fragmentation of A.[10] Besides the molecular ion signal at $m/z$ 154, there is a prominent peak at $m/z$ 153. This can be accounted for in mechanistic terms, and lends strong support to the structure.

[10] Mass spectrometry, in its simplest form, involves ionization of a molecule with high energy electrons, and detecting ions, or their fragmented units according to their mass to charge ratio. This is a valuable tool for determination of the molecular mass, as well as for structure elucidation — since the fragmentation pattern is unique for a given molecule.

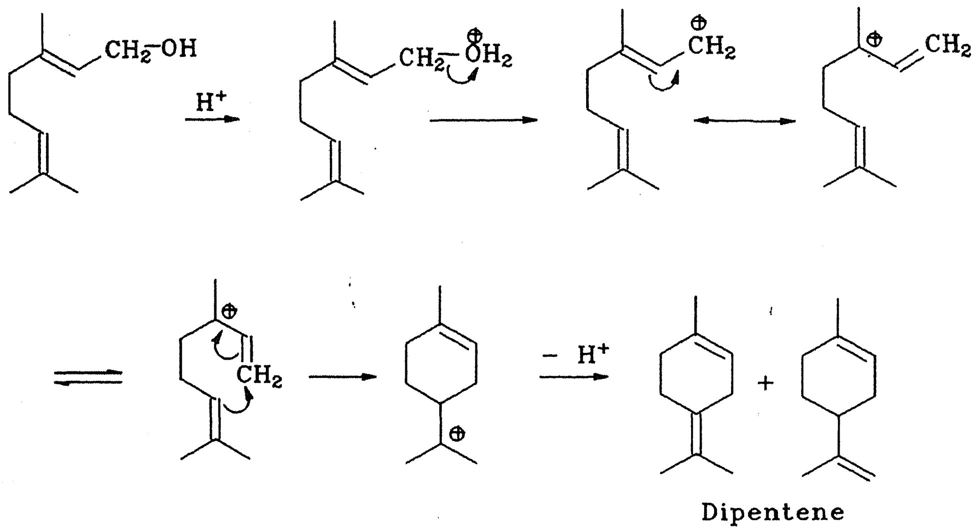
Finally, the structure of geraniol is confirmed by synthesis. Whereas the analytical approach involves the dissection of the molecule into smaller recognizable units, the synthetic approach involves the reconstruction of the proposed structure from smaller molecules using predictable and unambiguous reaction pathways. One synthetic approach is shown in *Scheme 4*. Explanatory notes have been deliberately omitted as the students should themselves logically determined each and every step of the reaction sequences.

**The analytical approach involves the dissection of the molecule into smaller recognizable units; in the synthetic approach we reconstruct the proposed structure from smaller molecules using predictable and unambiguous reaction pathways.**

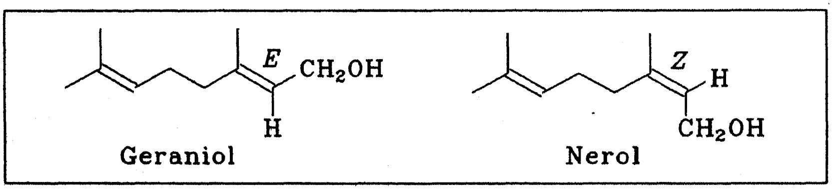
We conclude this brief account of the chemistry of geraniol with a short note on its stereochemistry. This compound is optically inactive and non-resolvable, but can assume several conformations. On acid catalyzed dehydration, geraniol yields dipentene as one of the products. The formation of this cyclic terpene which can be rationalized, as shown in *Scheme 5*, illustrates the importance of appropriate conformations in intramolecular reactions. This example can also be used for demonstrating the formation, stability and fate of a carbocation.




**Scheme 4**




**Scheme 5**

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As can be seen from the structure (box in Scheme 5), geraniol has the *E* configuration at the unsymmetrically substituted double bond. The *Z* isomer also occurs in nature and is known as nerol. Nature converts geraniol into nerol via geranyl pyrophosphate. The two configurational isomers (diastereomers) have separate existence. However, upon oxidation, both geranial and neral give a mixture of aldehydes (citral) which is an inseparable mixture of geraniol and neral. (Can you explain why the two diastereomers of the aldehyde co-exist in contrast to those of the parent alcohol? A related problem is how you would prove that geraniol has the *E* configuration?)

# The Honeybee Dance-Language Controversy

## Robot Bee Comes to the Rescue

*Raghavendra Gadagkar*

**Language is usually credited with being the major factor in making humans so different from other higher animals. The fact that honey bees have a dance language that is unparalleled in the rest of the animal kingdom is therefore of great interest. Successful forager bees communicate information about the source of food discovered by them, to their sisters upon returning home. They do this by means of a round dance (which only says, there is food nearby) or a waggle dance which gives information about the distance, direction and quantity of food to be expected. Karl Von Frisch bagged the Nobel Prize in 1973, mainly for deciphering the dance language of honey bees. However there are some sceptics who believe that the dance that the foragers do perform may have no communication value and that bees locate sources of food based on the scent left behind by the discoverer on the way to and at the location of the food source. While bees can find food based on such odours, recent experiments, using a robot bee, convincingly demonstrate that bees can also find food, in the absence of smell, on the basis of information communicated through the dance language.**

Raghavendra Gadagkar, who studies and teaches animal behaviour at the Centre for Ecological Sciences, Indian Institute of Science and Jawaharlal Nehru Centre for Advanced Scientific Research, has a particular fascination for social insects such as ants, bees and wasps. He hopes to provide a Darwinian explanation for the altruism, courage, industry, sacrifice and such other seemingly human attributes of these insects.

### Language - The Prime Mover

Humans and chimpanzees share 99% of their genetic information. What then makes us so different from chimps? Our language is often credited with being the prime mover in making humans what they are. We have a unique ability to modulate our vocalizations because of the unusual structure of our vocal tract. For this we incidentally pay the price of the risk of choking to death while eating or drinking. Non-human apes can neither produce compa-

**The waggle dance has been shown to convey information on the distance between the colony and the food, the direction in which the food source is located as well as an indication of how much food is to be expected.**

rable variations in sound nor do they choke as they can simultaneously eat or drink and breathe. The unique structure of our vocal tract, taken together with our superior brains that permit us to detect virtually infinite variations in sound and associate them with objects or thoughts in an arbitrary and symbolic (see below) manner, lead to man's unparalleled ability to communicate and change the world. The only sobering fact is that we are not quite alone, at least in our ability to use a symbolic language. The only other example of a well-developed system of associating environmental stimuli in an arbitrary and symbolic manner with "universally understood meanings" is seen in the dance language of the honey bee. The claim is not that honey bees come anywhere near humans in their communication skills but that no other non-human animal, vertebrate or invertebrate, can match even the bee dance language.

## Honey Bees

Honey bees live in extremely populous colonies and maintain an elaborate social organization. Every colony has a single queen, a few hundred drones (males) and tens of thousands of workers (all females). The queen is an egg laying machine and a chemical factory. She is responsible for all eggs laid in the colony and she manipulates the behaviour of the workers through various pheromones (chemical messengers) that she releases from time to time. The workers take on the responsibilities of nest construction and maintenance, brood care, and foraging for nectar and pollen from the environment. The drones do nothing for the colony itself and are chased away (often with limited success) during times of food scarcity. The success of honey bees to maintain such large colonies can be attributed to their ability to efficiently harvest large but ephemeral sources of pollen and nectar from flowers in their neighborhood. This in turn depends crucially on the unique ability of a successful forager bee to quickly recruit large numbers of naive workers from its colony to a newly found source of food. After decades of painstaking observations and many false starts, the Austrian zoologist Karl von Frisch *(Figure 1)* discovered and

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***Figure 1** Karl Ritter von Frisch, recipient of the Nobel Prize in 1973 for his discovery of the honey bee dance language.*

deciphered the honey bee dance language which enables such recruitment.

## The Dance Language

A successful forager that returns to the colony attracts the attention of her sisters by means of a chemical she releases upon arrival. This usually ensures her an attentive audience to begin her dance. The forager, who alone possesses information on the location of food, performs either a *round dance* or a *waggle dance (Figure 2)*. During a round dance the bee runs in small circles, often alternating between clockwise and counterclockwise directions. During the waggle dance, the forager waggles her body from side to side about 13 times per second while running in a straight line, and then returns to the starting point without waggling her body, in a clockwise or counterclockwise direction. She then repeats the waggle run, thus inscribing a figure of eight. The round dance is performed if the food is within 100m or so of the colony and the waggle dance is performed if the food is located beyond that. The round dance appears to provide no more information than that there is food close by. But the waggle dance has been shown to convey information on the distance between the colony and the food, the direction in which the food source is located as well as an indication of how much food is to be expected. The dancer also carries the smell of the pollen and/or nectar that she has recently encountered and that adds to the knowledge of the potential recruits, both during the round dances as well as during the waggle dances.

**The bee uses gravity and not the sun as the reference point while dancing.**

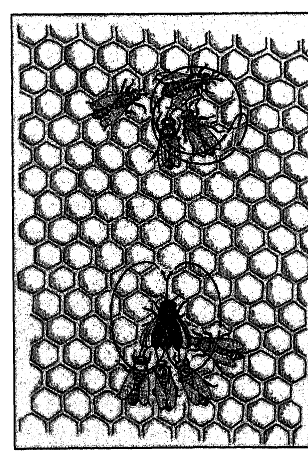
SANJEEVA NAYAK

***Figure 2** Dancers and their followers. (Top): round dance and (Bottom): waggle dance.*

## Is It a Language?

The direction of the waggle run contains information about the direction of the food. Most species of honey bees dance on the vertical surface of the nest which is built inside a dark cavity. Hence the bee uses gravity and not the sun as the reference point while dancing. For this the bees have to transform the angle between the sun (or, to be more precise, the sun's azimuth,

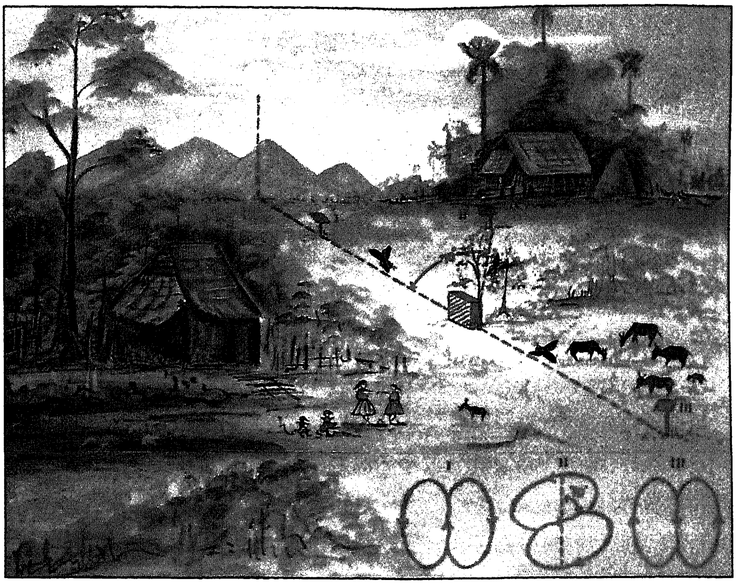


*Figure 3 The waggle dance orientations illustrated for three different positions of the food source. When the food is in the direction of the sun as in I, the waggle run is directed upwards and when the food source is in the direction opposite to the sun, the waggle run is directed downwards. When the food is 80 degrees to the left of the sun, the waggle run is 80 degrees to the left of the vertical.*

meaning its projection on the horizon), the food, and their nest, into an angle with respect to the vertical. This is where the arbitrariness comes in. The symbolic representation that all bees seem to have "agreed" upon is to represent the direction of the sun with a waggle run pointing straight up, a direction against the sun with a waggle run pointing straight down, a location of food 60 degrees to the right of the sun with a waggle run direction 60 degrees to the right of the vertical, and so on (*Figure 3*). Every direction in the outside world can thus be accurately conveyed by the angle of the waggle run except only when the sun is exactly overhead at the equator (when the bees simply rest for a few minutes!). The number of figure eight circuits made per unit time and the duration of each waggle run indicate the distance between the nest and the food source. There are good reasons to call this communication system of the honey bee a language. Firstly, the bee language conveys information about something at great distance and not visible at the time of communication. The notations are arbitrary; "up" means in the direction of the sun because that is what the bees seem to have "agreed" upon, but it could as well have been that "down" means in the direction of the sun. More interestingly, the bee dance language also has dialects. There are slightly different calibrations of the figure of eight circuit dura-

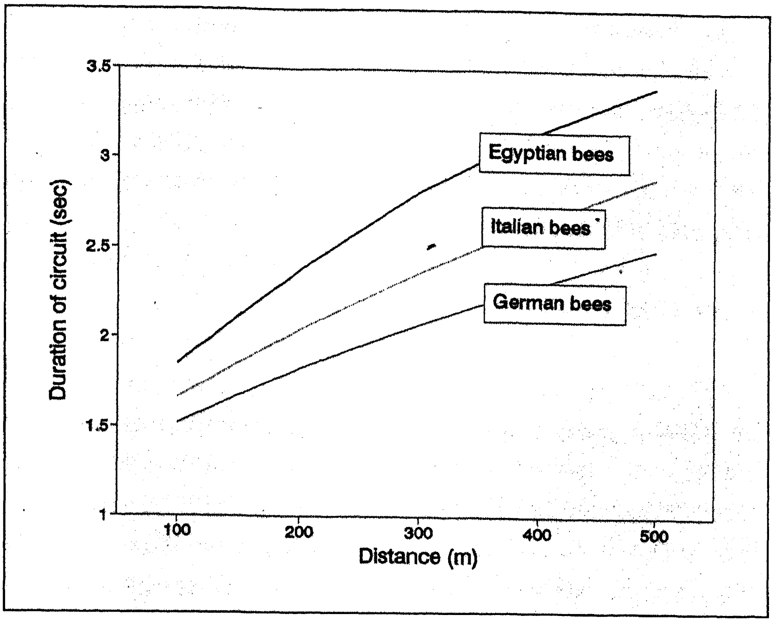


***Figure 4 Different dialects of Egyptian, Italian and German bees. The distance corresponding to a circuit duration of 2.5 seconds for example, is about 200m for Egyptian bees, about 300m for Italian bees and about 500m for German bees.***

tion with distance depending on the races of bees one is looking at (*Figure 4*).

## The Controversy

Karl von Frisch won the Nobel prize in 1973 for this discovery in spite of a challenge to his theory of the dance language thrown up by two scientists from California, Adrian Wenner and Patrick Wells. Their claim was that von Frisch's decoding of the dance language was a mere delusion and that bees really locate food discovered by their sisters by means of scent left by the original discoverer on the way to and at the location of the food. This counter argument cannot be dismissed out of hand because bees have a very well developed sense of smell. They are indeed capable of finding food discovered by their sisters by means of the scent of the discoverer on the way to and at the location of the food, under some circumstances. However, the question is not so much whether bees can ever locate a food source successfully by means of odour cues left by the discoverer. The question of interest is whether bees can ever successfully communicate using a symbolic, arbitrary dance language without the need for scent marks

**The question of interest is whether bees can ever successfully communicate using a symbolic, arbitrary dance language without the need for scent marks of the discoverer along the way to and at the target location. This can only be tested by eliminating the scent marks of the discoverer and retaining only the information provided by the dancer.**

of the discoverer along the way to and at the target location. This can only be tested by eliminating the scent marks of the discoverer and retaining only the information provided by the dancer. This was accomplished in an ingenious way by James L Gould of Princeton University. He made the bees "lie" and proved the existence of a true language!

## Bees Can Tell Lies

If a bee nest is removed from its normally dark cavity, the dancers need no longer use "up" to mean in the direction of the sun; they can as well aim their waggle runs in the direction of the food source using the sun directly as a reference point. The waggle runs can now be in the direction of the sun, away from the direction of the sun or 60 degrees to the right of the sun and so on, depending on where the food is located. A nasty trick used by Gould was to place a powerful source of artificial light close to the nest. When you do this the bees then ignore the sun and confuse this light for the sun. In other words, they orient their dances with reference to this artificial sun. If the light is placed in a position very different from that of the real sun, bees use the real sun while foraging, and the artificial sun while dancing and thus communicate completely wrong information. In addition to their two compound eyes, honey bees have three simple eyes called ocelli on the back of their heads. These ocelli are used to sense the intensity of light and help bees to decide when to start and when to stop foraging. The ingenuity of Gould's experimental design was to paint the ocelli of the dancers so that they could not see the bright light. They therefore reverted to using gravity for conveying orientation and let us say indicated 60 degrees to the right of "up" because the food was located 60 degrees to the right of the real sun. However, the recruits (the dance followers) had normal unpainted ocelli and mistook the bright light to be the sun. Thus the recruits were expected to go to the misunderstood location, 60 degrees to the right of the bright light instead of going to the true location, 60 degrees to the right of the real sun. Gould of course was waiting at this "wrong" location (60 degrees to the right of the artificial

light, at the appropriate distance) where he was confident the recruits would go and sure enough he was rewarded by the arrival of the bees! Notice that the bees should have gone to the correct location, 60 degrees to the right of the real sun if they had relied on the scent of the dancers on the way to and at the location of the food. Although von Frisch retained the Nobel Prize, even this elegant experiment did not set the controversy to rest.

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## The Robot Bee — A Novel Solution

The main problem is that we cannot claim to know exactly what it is that the dancer is telling the recruits. What we need is to be able to talk to bees in their own language and restrict communication to only those elements of the language that we have deciphered. Sounds impossible, does it not? Well, not quite. A Michelsen and B B Andersen from Denmark and Wolfgang Kirchner and Martin Lindauer from Germany have constructed a mechanical "robot" bee that talks to the real bees through a computer, programmed by the scientists based on their idea of the bee dance language and, believe it or not, the bees understand! The robot bee was made of brass and was about the size of a real bee *(Figure 5)*. It was coated with a thin layer of wax and made to sit in the nest among the real bees for about 12 hours and thus came to smell like the bees. It had wings made of razor blades which when vibrated produced acoustic signals similar to those

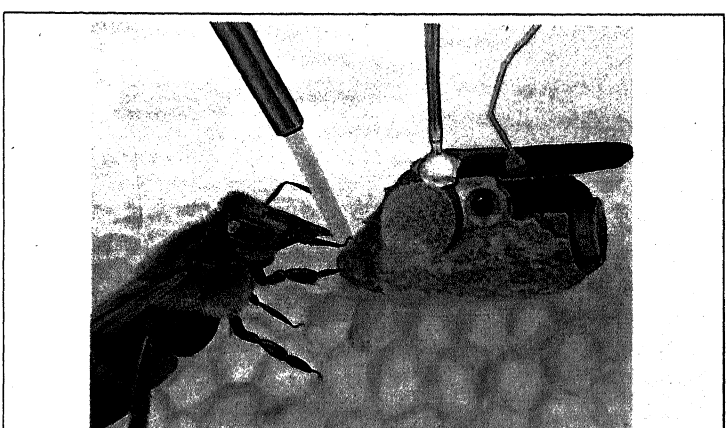

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***Figure 5** Robot bee offering food to a real bee.*

produced by real dancing bees. Two rods attached to the robot bee helped control its movements through a computer program. Most importantly a plastic tube near the model's head delivered, like the real bee, a drop of sugar solution from time to time. This was essential to prevent the real bees from attacking the model! Now by making the robot bee perform a waggle dance with a particular orientation of the waggle run, Michelsen and Co. thought that they could make the bees go wherever they wished them to go and sure enough they were right! This gives us confidence that our understanding of the bee dance language is sufficient to make the bees understand the true meaning of a message. This should lay the controversy to rest and vindicate the Nobel Laureate's theory but, knowing human nature, Wenner and Adrian are not going to be convinced. That won't be so bad really because it will motivate someone to do an even more ingenious experiment— science, after all, thrives on controversy and a penchant for disbelieving others' findings.

## Suggested Reading

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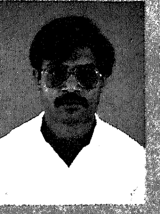
# Fermat's Last Theorem

## A Theorem at Last!

*C S Yogananda*

**After more than three centuries of effort by some of the best mathematicians, Gerhard Frey, J -P Serre, Ken Ribet and Andrew Wiles have finally succeeded in proving Fermat's assertion that the equation $X^n + Y^n = Z^n$ has no solutions in non-zero integers if $n \geq 3$. Each of the four mathematicians made a decisive contribution with Wiles delivering the *coup de grace*. The proof, as it finally came to be, is in some sense a triumph for Fermat.**



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When Pierre de Fermat died in 1665 he had not published a single mathematical work (except for an anonymous appendix to a book written by a colleague). His mathematical discoveries were contained in his correspondence with other mathematicians of his time, notably, Pascal, Frénicle de Bessy and Father Mersenne. He also left behind a few unpublished manuscripts and marginal notes in the books studied. We have to be grateful to his son Samuel for whatever we know of Fermat's work. Samuel de Fermat went through his father's papers and books in addition to soliciting letters written by his father from his correspondents in order to publish them. Among Fermat's possessions was a copy of the Latin translation, by Bachet, of Diophantus' *Arithmetic* in which Fermat had made a number of marginal notes.

The first work Samuel chose to publish, in 1670, was a new edition of Bachet's Diophantus with an appendix containing forty eight marginal notes made by Fermat. The second of these notes appears alongside problem 8 in Book II of *Arithmetic*: "*... given a number which is square, write it as a sum of two other squares*". Fermat's note states, in Latin, that "*on the other hand, it is impossible for a cube to be written as a sum of two cubes or a fourth power to be written as sum of two fourth powers or, in general, for any number which is a power*

***"On the other hand, it is impossible for a cube to be written as a sum of two cubes or a fourth power to be written as sum of two fourth powers or, in general, for any number which is a power greater than the second to be written as a sum of two like powers. I have a truly marvellous demonstration of this proposition which this margin is too narrow to contain".***

*greater than the second to be written as a sum of two like powers. I have a truly marvellous demonstration of this proposition which this margin is too narrow to contain".* Thus, it was in 1670 that the world learnt of what has come to be termed Fermat's Last Theorem (FLT): The equation

$$X^n + Y^n = Z^n$$

has no solutions in non-zero integers if $n \geq 3$. Fermat himself had given a proof of this assertion for $n = 4$ using *infinite descent*, a method he invented, and Euler proved the case $n = 3$. Thus to prove FLT we need to show that $X^p + Y^p = Z^p$ has no solutions in non-zero integers whenever $p$ is a prime greater than 3 (do you see why?).

After more than three centuries of effort by some of the best mathematicians, Gerhard Frey, J -P Serre, Ken Ribet and Andrew Wiles have finally succeeded in proving Fermat's assertion, each of them making a decisive contribution with Wiles delivering the *coup de grace*. The proof, as it finally came to be, is in some sense a triumph for Fermat. *Elliptic curves and infinite descent* play significant roles and it was Fermat who pioneered the use of elliptic curves in solving diophantine equations and it is to him that we owe the method of infinite descent.

## Diophantine Equations

The chief work of Diophantus of Alexandria (c. 250 A.D) known to us is the *Arithmetic,* a treatise in thirteen books, or *Elements*, of which only the first six have survived. This work consists of about 150 problems, each of which asks for the solution of a given set of algebraic equations in positive rational numbers, and so equations for which we seek integer (or rational) solutions are referred to as diophantine equations. The most familiar example we know is $X^2 + Y^2 = Z^2$ whose solutions are *Pythagorean triples;* (3, 4, 5), (5, 12, 13) are examples of such triples. If, instead, we ask for solutions, in integers, of $X^2 + Y^2 = 3Z^2$ we get an example of a

antine equation for which there are no solutions in non-zero
ers. (To see this, first observe that we may assume $X$, $Y$, $Z$ to
irwise relatively prime, by cancelling common factors, if
nd that any square when divided by 3 leaves remainder 0 or
fact, it is an interesting exercise to characterize the set of
al numbers $m$ for which the equation $X^2 + Y^2 = mZ^2$ has no
ons in non-zero integers.

nderstand the role of *geometry* in solving diophantine equa-
let us consider the equation $X^2 + Y^2 = Z^2$ . How do we
cterize all solutions (in integers) of this equation? We could
ne again that $X$, $Y$, $Z$ is a *primitive* solution, i.e., $X$, $Y$, $Z$ are
ise relatively prime. Dividing by $Z^2$ and putting $X/Z = x$
$/Z = y$ we get $x^2 + y^2 = 1$, that is to say, we get a *rational point*
nt both of whose coordinates are rational numbers), $(x,y)$, on
nit circle centred at the origin. Conversely, a rational point
e circle $x^2 + y^2 = 1$ will give us a (primitive) Pythagorean
. So, our problem reduces to finding all rational points on
nit circle. We do this by drawing a line with rational slope
ng through the point $(-1, 0)$. This line will meet the circle at
nore point and we claim that this point is also rational. I shall
it to you to figure out why it is so. (You need to use the fact
f one root of a quadratic equation with rational coefficients
onal then the other root is also rational.) This way we obtain
tional points on the circle. Put $t = \tan \theta/2$ in the familiar
netrisation of the circle, $(\cos\theta, \sin\theta)$. Then we get the
known characterisation of the Pythagorean triples: if $m$
, $m > n$, are integers of opposite parity then the numbers

$$m^2 - n^2, 2mn, m^2 + n^2$$

a primitive Pythagorean triple and every primitive Pythago-
triple arises this way.

method can be used to find all rational points on a conic
n whose defining equation has rational coefficients once we
ole to find one such point.

**History of FLT**

- 1640, Fermat himself proved the case $n = 4$
- 1770, Euler proved the case $n = 3$; (Gauss also gave a proof).
- 1823, Sophie Germain proved the *first case* of FLT — first case of FLT holds if there is no solution for $X^p + Y^p = Z^p$ for which $p$ does not divide the product $XYZ$ — for a class of primes, *Sophie Germain primes*: primes p such that $2p+1$ is also a prime.
- 1825, Dirichlet, Legendre proved FLT for $n = 5$.
- 1832, Dirichlet treated successfully the case $n = 14$.
- 1839, Lamé proved the case $n = 7$.
- 1847, Kummer proved FLT in the case when the exponent is a *regular prime*. But it is not known even today whether there are infinitely many Sophie Germain primes or regular primes.
- 1983, Faltings gave a proof of Mordell's conjecture.
- 1986, Frey - Ribet - Serre: Shimura - Taniyama - Weil conjecture implies FLT.
- 1994, Andrew Wiles: proof of S-T-W conjecture for semistable elliptic curves.

**What is *elliptic* about elliptic curves?**

Ellipses are not elliptic curves! Elliptic curves are so called because it was in connection with the problem of computing arc lengths of ellipses that they were first studied systematically. When we compute the arc of a circle, we have to integrate the function $1/\sqrt{(1-x^2)}$, which we do in terms of the sin and cos functions. The trigonometric functions are therefore called *circular functions.* Similarly, to compute the arc length of an ellipse we have to integrate functions of the form

$$1/\sqrt{[(1-x^2)(1-k^2x^2)]}.$$

This integral cannot be computed using circular functions and mathematicians worked on this problem for many years before Abel and Jacobi, independently introduced *elliptic functions* to compute such integrals. Just as sin and cos satisfy $x^2 + y^2 = 1$, the elliptic functions satisfy an equation of the form $y^2 = f(x)$ where $f(x)$ is a cubic.

## Elliptic Curves

Consider the following classical problems.

(i) Find all $n$ such that the sum of the squares of first $n$ natural numbers is a square. That is, we have to find natural numbers $n$ and $m$ such that

$$m^2 = n(n+1)(2n+1)/6.$$

(ii) (Diophantus) Find three rational right triangles of equal area.

Let $A$ denote the area of the right triangle with sides $a$ $(=p^2-q^2)$, $b$ $(=2pq)$ and $c$ $(=p^2+q^2)$; thus $A = pq\,(p^2-q^2)$. Then if we put $x = p/q$ we get a rational point $(p/q, 1/q^2)$ on the curve

$$Ay^2 = x^3 - x.$$

Conversely, if $(a/b, c/d)$ is a rational point on this curve then the right triangle with $d\,(a^2-b^2)/b^2c$ and $2ad/bc$ as legs also has area equal to $A$.

(iii) (From an Arab manuscript dated before the 9th century) Given a natural number $n$, find a rational number $u$, such that both $u^2 + n$ and $u^2 - n$ are squares (of rational numbers).

If such a $u$ can be found then $n$ is called a congruent number. A number $n$ being congruent is equivalent to the existence of a right triangle with rational sides and area $n$.

Suppose $n$ is a congruent number and let $u$ be such that $u^2 + n = a^2$ and $u^2 - n = b^2$. Multiplying the two equations together we get

$$u^4 - n^2 = (ab)^2.$$

Multiply by $u^2$ throughout to get

$$u^6 - n^2u^2 = (abu)^2.$$

Putting $u^2 = x$ and $abu = y$ we get a rational point on the curve, E, defined by the equation

$$y^2 = x^3 - n^2x.$$

*Exercise:* Conversely, if $(x,y)$ is a rational point on $E$ such that $x$ is a rational square and has even denominator then $n$ (whose square appears as the coefficient of $x$) is a congruent number.

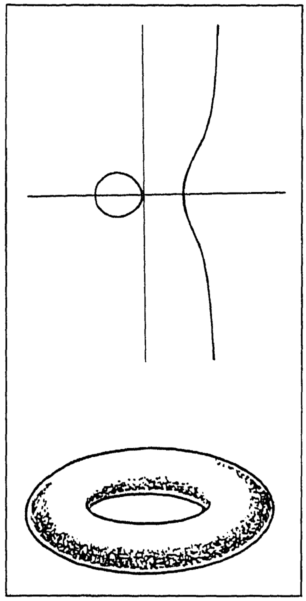

*Figure 1* **Typical illustration of how the real / complex points on an elliptic curve look like.**

In each of the above problems we were led to consider equations of the form $y^2 = f(x)$, where $f(x)$ is a cubic polynomial in $x$ with rational coefficients and distinct roots. Such equations define *elliptic curves*. We could think of elliptic curves as the set of all rational / real / complex solutions of such equations. The set of all complex solutions of an elliptic curve can be identified with the points on a *torus*. The adjacent figures *(Figure 1)* show what the real and complex points on an elliptic curve look like.

Finding rational points on an elliptic curve turns out to be a difficult problem and though many deep results have been proved (one of them by Andrew Wiles along with John Coates), a lot remains to be done in this area. The study of elliptic curves is currently a very active field of research involving many different areas of mathematics.

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If we try to imitate the method we used for a conic to get more rational points from one such point we are stuck. This is because a line meets a cubic curve, generally, in three points and we cannot conclude that the other points of intersection are rational. That is, if one root of a cubic equation with rational coefficients is rational the other two roots could be irrational; they could be conjugate surds, for instance. What is true is that if you draw the line joining two rational points then the third point where this line meets the cubic will also be a rational point. Thus, we can 'add' two rational points to get a third rational point. It turns out that we could take the 'point at infinity' as the identity or the 'zero' element and obtain a structure of a *group* (in fact, a commutative group) on the

set of rational points of an elliptic curve by declaring the sum of three collinear points to be zero; the inverse or 'negative' of the point $(x,y)$ is the point $(x,-y)$. Thus, to add two points $P$ and $Q$ join them by a straight line, find the third point of intersection of the line with the curve and reflect it in the x-axis to get a point, $R$, on the curve which will then be the 'sum' of $P$ and $Q$.

> *Exercise:* Consider the elliptic curve, $E$, defined by the equation $y^2 = ax^3 + bx^2 + cx + d$. Obtain an expression for the coordinates, $x_3, y_3$, of the sum of the two points $P = (x_1,y_1)$ and $Q = (x_2,y_2)$ on $E$, in terms of $x_1, x_2, y_1, y_2$.
> *Hint:* If $P$ is not equal to $Q$, $x_3 = -x_1 - x_2 - (b/a) + (y_2 - y_1)^2 / a(x_2 - x_1)^2$ and if $P = Q$, $x_3 = -2x_1 - (b/a) + (f'(x_1))^2 / a(2y_1)^2$ where $f(x)$ denotes the cubic.

**The structure of a group on the set of rational points of an elliptic curve provides us with a powerful tool to study diophantine equations.**

The structure of a group on the set of rational points of an elliptic curve provides us with a powerful tool to study diophantine equations. For instance, in problem 2 above if we get one rational point then we could 'double' (i.e. draw a tangent at that point) it to get one more point and then add these two to get yet another point, and so on. In fact, this is what Fermat used to get more solutions to the problem (even Diophantus used this procedure but he gave only three rational points). In the congruent number problem, it turns out that the double of any rational point which is not of order 2 is such that the x-coordinate is a square number with even denominator.

The method we used to show the non-existence of solutions of $X^2 + Y^2 = 3Z^2$ by showing that the equation has no solutions *modulo 3* is a standard method we use in studying diophantine equations. Assume that the equation has integer coefficients by clearing the denominators, if necessary. We *reduce* the equation modulo a prime $p$ by replacing the coefficients of the equation by their remainders when divided by $p$ and consider the set of solutions of the reduced equation in the *finite field* $\{0, 1, 2,.. p-1\}$. If, for example, we find a prime for which there are no solutions

for the reduced equation it follows immediately that the original equation has no rational roots.

Consider an elliptic curve $E$ defined by $y^2 = f(x)$. Except for a finite set of primes depending on the cubic $f(x)$ the reduced equation will also define an elliptic curve. In fact, the *exceptional* set of primes is precisely the set of prime divisors of the discriminant of the cubic $f(x)$. For a prime $p$ not dividing the discriminant let $N_p$ denote the number of points of $E$ modulo $p$, i.e., the number of pairs $(x, y)$, with $x, y$ in $\{0,1,2,..., p-1\}$ , satisfying the equation modulo $p$. Define integers $a_p$ by

$$N_p = p + 1 - a_p.$$

These $a_p$'s could be positive or negative and Hasse proved the following inequality in 1930:

$$|a_p| \leq 2\sqrt{p}.$$

These numbers $a_p$ contain a lot of information about the rational points of the elliptic curve and there are many conjectures concerning their properties among which the Birch – Swinnerton - Dyer conjecture and the Shimura – Taniyama – Weil conjecture are the most important.

**The general feeling among mathematicians following Falting's proof of the Mordell conjecture was one of satisfaction since there was no reason or heuristic basis as to why FLT should be true; *at most finitely many solutions* was good enough.**

The content of the Shimura - Taniyama - Weil (S-T-W) conjecture is that these $a_p$' s are the *Fourier coefficients of a cusp form* (of weight 2 and a certain level $N$). The definition of cusp forms is beyond the scope of this article and we content ourselves by saying that they are certain functions on the upper half-plane (please see *Suggested Reading* at the end). Elliptic curves for which the $a_p$' s satisfy the S-T-W conjecture are called *modular* elliptic curves.

## Frey Elliptic Curve and Fermat's Last Theorem

The study of rational points on higher degree curves witnessed a breakthrough in 1983 when Gerd Faltings proved a conjecture of Mordell. As a corollary it followed that the curve $X^n + Y^n = 1$ has

**Fermat's favourite target for his problems and challenges were the English mathematicians; after all he was French! Thus it is fitting that his most famous challenge has been answered by Wiles, an Englishman, though it took a while (A Wiles!) coming!**

only finitely many rational points if $n \geq 5$ which means that there would be at most finitely many solutions to the Fermat equation

$$X^n + Y^n = Z^n.$$

The general feeling among mathematicians following this was one of satisfaction since there was no reason or heuristic basis as to why FLT should be true; *at most finitely many solutions* was good enough.

But FLT bounced back soon after in 1985 when Gerhard Frey linked a counter example of FLT, if there is one, with an elliptic curve which did not seem to satisfy the S-T-W conjecture! Frey's was a simple but very ingenious idea: if, for some prime $p > 3$, there are non-zero integers $u,v,w$ such that $u^p + v^p = w^p$ then consider the elliptic curve, now referred to as the *Frey curve*,

$$y^2 = x(x + u^p)(x - v^p).$$

Thus for the first time, FLT for *any exponent* was connected with a *cubic* curve instead of the higher degree curve which the equation itself defines.

Then things started happening fast and in the summer of 1986, building on the work of Frey and Serre, Ribet succeeded in proving that S-T-W implies FLT by showing that the Frey curve could not be modular. Now, FLT was not just a curiosity but was related to a deep conjecture; if it were not true and we had a counter example, the Frey curve would be sticking out like a sore thumb!

Soon after he heard of Ribet's result, Andrew Wiles went to work on the S-T-W conjecture in the late summer of 1986. After working hard on it for seven years, during which even his closest friends did not get to know what he was up to, Wiles stunned the mathematical world by claiming that he had proved the FLT by proving a particular case of the S-T-W conjecture, the case of *semi-stable* elliptic curves. He made the announcement at the end of a

series of lectures at the Isaac Newton Institute in Cambridge, England on the morning of Wednesday, June 23, 1993. But experts checking his proof found many gaps of which he could overcome all but one. It is to the credit of Wiles that he did not let this setback deter him. Rather, encouraged and mathematically supported by his students and close friends, notably Henri Darmon, Fred Diamond and Richard Taylor, he circumvented the gap in September 1994. His paper, along with another one of his jointly with Richard Taylor, occupies one whole issue of the leading journal *Annals of Mathematics*, 142 (1995). It should be remarked that the theorem Wiles proves is a very significant result with far-reaching consequences and FLT follows as a simple corollary.

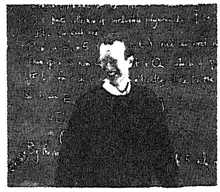

***Figure 2 Andrew Wiles who delivered the final* coup de grace *in the proof of FLT.***

Apparently, Fermat's favourite target for his problems and challenges were the English mathematicians; after all, he was French! Thus, it is fitting that his most famous challenge has been answered by Wiles, an Englishman *(Figure 2)*, though it took a while (A Wiles!) coming!

## Suggested Reading

**Paulo Ribenboim. 13 Lectures on Fermat's Last Theorem. Springer-Verlag. 1979.**

**H M Edwards. Fermat's Last Theorem: A Genetic Introduction to Algebraic Number Theory. Springer-Verlag. 1977.**

**The two books above contain historical accounts of the various attempts to prove FLT and developments stemming from these attempts, especially the work of Kummer.**

**J -P Serre. A Course in Arithmetic. Springer International Student Edition, 1979.**

**This extraordinary book covers in just hundred pages many important theorems in number theory (with proofs) and contains an introduction to modular forms.**

**Neal Koblitz. Introduction to Elliptic Curves and Modular Forms. Springer-Verlag. 1984.**

**This contains a beautiful introduction to elliptic curves and modular forms via the *congruent number problem*.**

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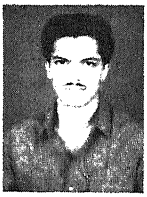
# What's New in Computers

## Windows 95

*Vijnan Shastri*



Vijnan Shastri works at the Centre for Electronics Design Technology in the Indian Institute of Science and his areas of interest are digital and microprocessor systems, storage subsystems and systems software.

**Windows 95 offers several new features and is undoubtedly a landmark development in software technology.**

### Evolution of Windows 95

There has been a lot of discussion around the release of Windows 95 on 24 August 1995, amidst much hype and marketing glitz. The media is full of speculation on what it will mean for the software industry and the end-users. In this article, we trace the evolution of Windows 95, look at its features and see what implications it has for the future.

**Apple's 'Macintosh' line of PCs, released in the early 1980's, had hardware capabilities and an operating system with a graphical user interface plus many of the features that Windows 95 has today.**

Around 1981, the PC with a 8088 CPU was introduced by IBM with the DOS operating system. The 8088 CPU was internally identical to the 8086 (i.e., it processed data 16 bits at a time), but externally did the reads and writes to memory, 8 bits at a time. A short while later Apple released its 'Macintosh' line of PCs which had better hardware capabilities and had an operating system which had a graphical user interface (GUI) plus many of the features that Windows 95 has today. This GUI enabled users to interact with the computer through graphical representation of objects rather than by typing cryptic, hard-to-remember commands (as in DOS). This graphical user interface meant that Apple had to use a display monitor with a good resolution, together with relatively better performance hardware. The crucial difference was that IBM made public the details of the hardware architecture of its PC (referred to as 'open architecture') leading to extensive 'cloning' by other manufacturers (the clones are referred to as IBM-compatibles) and consequently steep reduction in prices. Apple, on the other hand kept the architecture 'closed'. What proliferated among users in the years to come were


the IBM compatibles with DOS and DOS-based applications. This proliferation of DOS-based machines laid the foundation for Microsoft. Microsoft began working on its GUI operating system and introduced Windows (1.0) in late 1985. However, the average PC hardware at that time, despite phenomenal increase in performance wasn't still adequate for a hardware-resource-hungry Windows 1.0. Windows 1.0 never took off, but still Microsoft decided to pursue development of the Windows operating system.

Meanwhile, the evolution of the Intel processor was strongly influenced by the IBM-compatible DOS market and had to carry the 'DOS baggage' in every new processor (80386, 80486, Pentium and P6) that it has since introduced. Technically this meant that

- the processor be capable of operating simply as if it were a faster 8088 processor (called 'real-mode') where it processes data 16 bits at a time and can address only 1Megabyte (MB) of memory.

- the processor could also operate in an advanced 32-bit mode (called 'protected mode') where it has many advanced features (including addressing 4 Gigabytes of memory) plus a feature by which it could run in the 8086 mode, being on protected mode (called 'virtual 8086 mode').

**The average PC hardware around 1985 , despite phenomenal increase in performance, still wasn't adequate for a hardware-resource-hungry Windows 1.0. Windows 1.0 never took off.**

It must be remembered that Intel always maintained backward compatibility in the instruction set and this meant that software developed for a lower-end processor (such as 8088) would also run on the advanced processors without any change.

In 1990 Microsoft released Windows 3.0 which made use of some of the advanced features in the 80386 microprocessor. By this time the hardware (VGA- very high resolution graphics adapters for display, 4 MB of RAM memory, 80 MB of disk memory) had enough 'punch' to run Windows 3.0. Although DOS had a huge installation base on several million PCs, it was antiquated and was

**One of the keys to the success of Windows 3.1 was that it ran on top of DOS and used DOS for operations like file access, loading files etc. Users could therefore avail of both the powerful easy-to-use applications on Windows and the trusted DOS-based applications which they used for several years.**

inadequate for the computing needs of the nineties. These reasons made Windows 3.0 an instant success. With the subsequent release of Windows 3.1, Microsoft established its dominance over the IBM compatible - GUI operating system market, beating off competition from IBM's OS/2. One of the keys to the success of Windows 3.1 was that it ran on top of DOS and used DOS for operations like file access, loading files etc. Hence users on the one hand could avail of powerful easy-to-use applications on Windows but could also use trusted DOS-based applications which they used for several years. Thus the first major step in causing a transition from DOS to Windows was achieved. Windows 95, is essentially the next step in that direction. But where does Microsoft eventually want this to go? Microsoft eventually expects the transition to take place to its high-end, high-reliability feature-rich operating system : the Windows NT.

## Important Features of Windows 95

- *Improved GUI and general ease of use*

The user interface of Windows 95 is easier to use and more intuitive than ever before. The interface also makes it easy to setup and configure various components of the computer such as the printer, network interface and disc drives.

- *Plug-and-play feature for hardware*

In the past, considerable amount of time has been wasted by technicians and users trying to install different types of hardware (such as disk drives, and sound boards) which resulted in all types of hardware conflicts. A hardware conflict occurs when 2 cards (instead of one) get accessed for the same address or when two cards attempt to interrupt the CPU on a single line (interrupt lines cannot be shared). Resolving conflicts involves a painful process of changing connection (called 'jumpers') on the card and retrying. The idea of plug and play is to eliminate the need to change any jumpers on the card and to achieve configuration through

software. Thus the user simply 'plugs' the card and 'plays' the software and the installation is done. In order to achieve this, a plug-and-play standard for hardware manufacturers has been defined and Windows 95 is the first operating system to support this standard. Even for hardware that does not support this standard, Windows 95 has a lot of built-in support for 'nearly' plug-and-play capabilities.

- *Support for 32 bit applications (apps).*

Windows 3.1 ran applications that were 16 bit apps. This means that not only did they process data 16 bits at a time, but the movement of data from and to the processor was done 16 bits at a time. This was so even though the 80386, 486 and Pentium were 32 bit processors. This meant that these apps were under-utilizing the capabilities of the CPU, and thus paid a performance penalty. Windows 95 offers full support for 32 bit applications through its Application Programmer's Interface (API) thus leading to increased performance. At the same time Windows 95 is backward compatible which means it is capable of running the old 16 bit apps as well.

- *Pre-emptive multitasking for 32 bit apps*

Multitasking refers to the fact that the user can run more than one task at the same time. For instance, the user could be editing his document using a word processor and in the background another task could be transferring a file over the network. Essentially the CPU and other resources are shared between many tasks, giving the illusion that many tasks are being done at the same time. Pre-emptive means that a task can be interrupted (due to the occurrence of an event such as a mouse click or the time being a certain value - like an alarm clock) and another task run. Windows 3.1 also supported multitasking but this was cooperative in nature. This meant that once a task had begun to run it was up to the task to say to the operating system: "for the moment I don't need the CPU and other computer resources". The operating system would then

**Windows 3.1's support for multitasking was cooperative in nature. This meant that once a task had begun to run it was up to the task to say to the operating system: "for the moment I don't need the CPU and other computer resources".**

**In Windows 95 filenames can be up to 256 characters in length. It is therefore possible for a file to be named 'my physics lab work on October 25th 1995'. In DOS one would perhaps have named the file something like 'PHLOCT25.195'.**

decide to allot these resources to some other task. Pre-emptive multitasking improves performance considerably.

- *Support for long filenames*

In DOS, filenames cannot be more than 11 characters long and this created problems in documenting files. In Windows 95 filenames can be up to 256 characters in length. So for example, in Windows 95, it is possible for a file to be named 'my physics lab work on October 25th 1995'. In DOS one would perhaps have named the file something like 'PHLOCT25.195'.

- *Extensive built-in support for networking*

The earlier systems made it necessary to put together a large number of software programs in order to gain complete access to all the networks connected to the PC. Windows 95 integrates all these functions and makes network connectivity extremely easy to achieve. In addition, it is possible to do peer-to-peer networking with Windows 95. This means that PCs connected in a local area network can share disk drives and files. i.e., a PC's hard disk can be viewed as a hard disk of another PC connected to the same network. Software to browse through the Internet (called a 'Web Browser') is also integrated. In addition to network connectivity, support for fax, electronic mail and mobile computing is built-in.

- *Better support for multimedia*

Multimedia refers to the fact that digital data can now be presented in more than one medium: moving pictures (video) and sound. This essentially means that one can now view video clips together with sound on a PC and also control the playback. However the problem with multimedia applications is that they are resource hungry in terms of storage space requirements, computational power required and data transfer speeds. This entails use of special purpose hardware (to improve quality of video or 3-dimensional animation, for instance). Windows 95

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allows applications to easily access these special purpose hardware.

To summarize, Windows 95 offers a lot of new features and performance benefits. In order to get these performance benefits one must have the adequate hardware too: A 486 running at 66MHz with 16 MB RAM and a VGA display. However there are many who feel that the integration of many of the programs (which were earlier regarded as applications) into Windows 95, will further reduce competition for Microsoft in the applications market and this will lead to a total dominance of the desktop market by Microsoft, thus leading to their monopoly of this market. In addition, claims made by Microsoft, that it is a pure 32 bit operating system and its dependence on DOS is minimal have been questioned by experts. Nevertheless, Windows 95 is undoubtedly a landmark development in software technology and will certainly spur growth in areas such as multimedia, networking and plug-and-play technologies.

**There are many who feel that the integration of many of the programs (which were earlier regarded as applications) into Windows 95, will further reduce competition for Microsoft in the applications market and lead to its total dominance of the desktop market.**

**His father wanted him to be a bricklayer ...** In Brunswick, Germany, in 1780, a stonemason was calculating the wages due his workmen at the end of the week. Watching was his three-year-old son. "Father," said the child, "the reckoning is wrong." The boy gave a different total which, to everyone's surprise, was correct. No one had taught the lad any arithmetic. The father had hoped his son would become a bricklayer, but thanks to his mother's encouragement, the boy, Carl Friedrich Gauss (1777 - 1855), became one of the greatest mathematicians in history.

**The tireless mathematician ...** Leonhard Euler (1707 - 1783) authored 734 memoirs. And he did all this under a severe handicap, for he lost the sight of one eye in 1735, and the sight of the other in 1766. His skill in manipulation was remarkable, and his intuitive grasp of mathematics enormous.

# Nature Watch

## The Kokum Tree

*M D Subash Chandran*

**M D Subash Chandran combines teaching botany to under-graduate students and active research on forest history, coastal management, natural regeneration of forests and impact of forest-based industries on evergreen forests of Western Ghats.**

**The evergreen kokum tree found along the west coast of India is known not only for its beauty but also for its use as a condiment. Its economic and ecological potential make it ideally suited to the restoration of natural forests.**

A beautiful evergreen tree mainly found along the west coast of the Konkan, Goa, Karnataka and North Malabar, the scientific name of kokum is *Garcinia indica* Chois. Known as *brindon,* to the Portuguese in Goa, *bhirand or amsol* in Marathi and Konkani, *murgal* in Kannada and *punampuli* in Malayalam, the scientific name Garcinia is derived from Garcias who described it in 1574. It occurs from the sea level plains upto an elevation of about 800 m along the westward slopes of the Western Ghats. Kokum is also a cultivated tree; unfortunately, its propagation is being neglected these days. The famous Cooke's *Flora of the Bombay Presidency* published in 1901, mentions that 13,000 trees were estimated to be cultivated in Ratnagiri district.

The genus Garcinia with about 435 species, chiefly confined to the humid tropical forests of Asia, Africa and Polynesia, belongs to Clusiaceas (Guttiferae), a family of latex bearing evergreen trees and shrubs. Yellowish latex is a notable feature of all the *Garcinias.* The mangosteen, from *Garcinia mangastana* is one of the popular fruits from the tropics of the Far East.

*Figure 1 Garcinia indica.*

The kokum tree reaches a height of about 10 to 15 meters. Its dark green foliage, drooping branches and pyramidal shape make this slender tree look very graceful in a forest or garden *(Figure 1).* The simple and opposite leaves, about 10 cm x 5 cm, glabrous above and paler beneath, are red when young and dark green when mature. The tree comes to bloom from November to February and

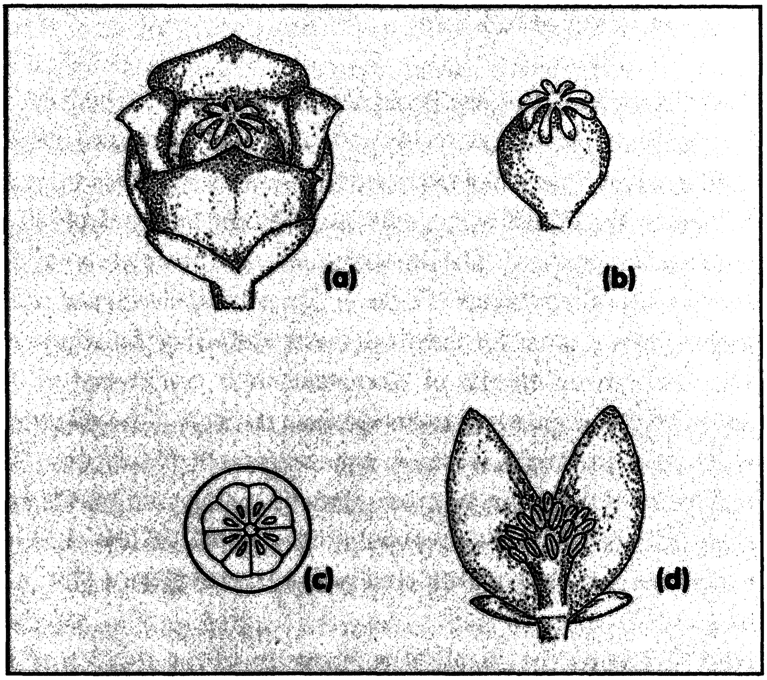


*Figure 2 (a) femal flower, (b) gynoeciu (c) cross section of ova and (d) male flower wi androecium exposed.*

the fruits ripen in April-May. The flowers are small and unisexual; the male and female flowers are found on the same tree. The calyx is of four free sepals and corolla of four free petals. The male flowers have 10 to 20 stamens. The female flowers have ovary of 4 to 8 chambers which is topped with a lobed and sessile stigma (*Figure 2*).

**The kokum tree in fruit is an attractive sight. The berries, usually deep purple to pink, occasionally whitish, are the size of a lemon. The fleshy rind of the fruit is juicy and acidic. Five to eight large seeds are embedded in a soft and sweet pulp.**

The tree in fruit is an attractive sight. The berries, usually deep purple to pink, occasionally whitish, are the size of a lemon. The fleshy rind of the fruit is juicy and acidic. Five to eight large seeds are embedded in a soft and sweet pulp.

There is not much information on the pollination of the kokum tree. However Clusiaceae family is known for bee pollination. In the Western Ghat forests, the butterfly *Papilo polymnestor* also visits the flowers of *Garcinia* spp. Bonnet monkeys, langurs, squirrels and fruit bats feed on the fruits of kokum. The monkeys also feed on the tender shoots. It is likely that frugivorous birds also eat the fruits.

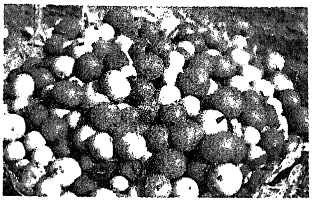

*Figure 3 Garcinia berries.*

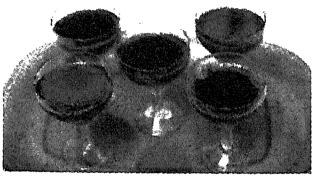

*Figure 4 Kokum juice - refreshing and medicinal.*

*Figure 5 The dried rind of Garcinia fruits.*

**The sides of the newly-laid Konkan Railway tract, which passes through coastal hills and valleys, would provide a promising habitat for raising thousands of kokum trees.**

## Uses of the Kokum Tree

The kokum tree is known for its various uses. The fleshy rind of the ripe fruits, which has a sweet and acidic taste, is sun-dried and used as a condiment like tamarind *(Figure 3)*. For the traditional fish curry from the Konkan coast and Goa the kokum fruit rind is an usual ingredient. The dried rind, strained in water, is boiled into a soup called *Solkadi (Figure 4)*. Spiced and sweetened with jaggery it is a must for marriage feasts and other functions in Uttara Kannada district of Karnataka. It is considered to be digestive. Wine red syrup extracted from the rind of the ripe fruit with the help of sugar, is stored in the household of the region for making cool drinks in summer. Various therapeutic effects are also attributed to it. The sweet pulpy cover of the seeds is eaten or made into curries. The fruit rind is also pickled *(Figure 5)*.

Notable among the chemical components of the dried rind is malic acid (about 10%). Tartaric acid is also present in it. About 44% by weight of the kokum seed kernel is an edible fat. The sun-dried seeds are crushed and subjected to boiling. The oil which collects on the surface, on cooling, solidifies into a cake which has a pale yellowish colour and bland taste. It melts at 36.5°C. Known as kokum butter this fat is used as a specific remedy for diarrhoea and dysentery. About 10 gm of the kokum butter is administered along with milk three times a day until complete recovery. It is also used for cooking purposes, more so when one is suffering from stomach disorders. The fat is an important traditional emollient used for applying on dry, chapped or cracked skin of feet and soles and lips and for various other skin ailments. It is now being used in cosmetics and medicines. Known as *Vrikshamla* in Ayurveda, various parts of the tree like root, bark, fruit and seed oil are used for treating piles, sprue and abdominal disorders.

## Conditions for Growth

Kokum prefers to grow in well drained lateritic soils. It is found

aturally in the fire protected secondary forests of the Western ɾhats and the west coast. It prefers partial shade rather than the pen area or the deep shade of evergreen forests. The seed, like ıat of most rain-forest species, has poor dormancy and germi-ates at the beginning of the rainy season. In the unprotected :ate, the saplings could succumb to cattle grazing, trampling and round fires. The tree is not usually grown as coppice.

## ;cological potential

'he favoured habitats for the kokum tree are the secondary forests lose to human habitation. Unfortunately, these are under great ressure. Kokum therefore requires greater attention from con-ɜrvationists. In the silviculture of Indian forests the kokum tree ppears to be almost ignored since it has no timber value. Of late, owever, saplings in large numbers are being raised in the forest urseries of coastal Uttara Kannada. This very useful and beauti-ıl tree is ideal for planting in parks and gardens, roadsides, and ı the compounds of houses and educational institutions. As the lant is associated with the vegetation of the ravines it should be :ied also for stabilising gullies and ravines of the west coast. 'here is enormous potential for raising beautiful avenues of okum trees alongside roads. The sides of the newly-laid Konkan ɩailway tract, which for most of its 750 km length passes through oastal hills and valleys, would provide a promising habitat for aising thousands of kokum trees. The tree, small in stature, ⁊ould not pose any problem to the road and rail traffic while roviding ecosystem and economical services of great value. 1oreover since the diameter of the canopy is only about 3 to 6 m, : can be grown safely in home gardens even in crowded urban reas. This tree is endemic to the Western Ghats and has great cological and economic potential. It should therefore be pre-ɜrred to the several exotics that are being planted widely these .ays. In the effort to restore natural forests of the Western Ghats, he kokum tree should be accorded the importance that it so richly .eserves.

## Suggested Reading


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# Molecule of the Month

## Cyclobutadiene in a Molecular Prison!

*Uday Maitra*

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**A novel way to isolate the highly reactive cyclobutadiene molecule is by trapping it inside a much larger molecule.**

Cyclobutadiene (1) has been one of the most popular molecules for experimentalists and theoreticians. This molecule is unstable as it is *antiaromatic* ($4\pi$ electrons in a cyclic array). Even though some highly substituted cyclobutadienes, for example, compound 2 and the $Fe(CO)_3$ complex of cyclobutadiene (3) are known, all attempts to isolate 1 under normal laboratory conditions have failed, since it reacts with itself, or with other molecules rapidly.

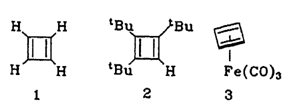
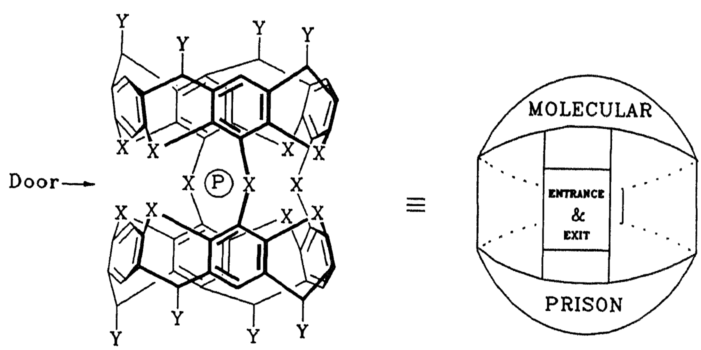



***Figure 1** Cyclobutadiene (1), compound 2 and $Fe(CO)_3$ complex of cyclobutadiene (3).*

The most logical way to reduce the reactivity of a molecule of 1 would be to put a *single* molecule of 1 in an unreactive "cage". Chemistry Nobel winner Donald J. Cram (1987) has shown that it is indeed possible (*Angew. Chem. Int. Ed. Engl.*, **30**, 1028. 1991)! Cram and co-workers synthesized a variety of spheroidal molecular prisons (*carcerands*) by linking two 'hemispheres' with three or four connecting units (see *Figure 2* below for carcerand 4). The molecular prison with three linkages is more like a prison with a




4: X = $-OCH_2O-$; Y = $(CH_2)_2Ph$

***Figure 2** Molecule P imprisoned inside 4.*

small door as shown. A molecule (whose size is similar to the space available inside the carcerand) can be made to go inside through the door under certain conditions. Once it is inside, you really have a single molecule floating around in the empty space (a fourth phase of matter?) created *within* a much larger molecule. One can then easily carry out unimolecular reactions on the molecule.

In order to 'imprison' cyclobutadiene, Cram and co-workers put a molecule of 5 inside carcerand (**4**). Photolysis of the complex of **4:5** first produces a new complex, **4:6**, which then loses $CO_2$ (too small to be trapped, it comes out rapidly through the door) and produces **4:1**, which is our cyclobutadiene trapped inside **4**! Spectroscopic studies on the complex **4:1** leaves no doubt that it is indeed **4** with cyclobutadiene inside. Prolonged photolysis of **4:1** was shown to produce acetylene. On the other hand, heating complex **4:1** with THF (tetrahydrofuran) resulted in an exchange of **1** with THF, and as soon as **1** came out of the prison, it dimerized to form **7**, which eventually produced cyclooctatetraene (**8**), as it does in a thermal reaction.

This example, therefore, gives us hope that many compounds which are thermodynamically unstable, can be isolated by making them kinetically inert by preventing their access to their decomposition pathways.

**This example gives us hope that many compounds which are thermodynamically unstable, can be isolated by making them kinetically inert by preventing their access to their decomposition pathways.**

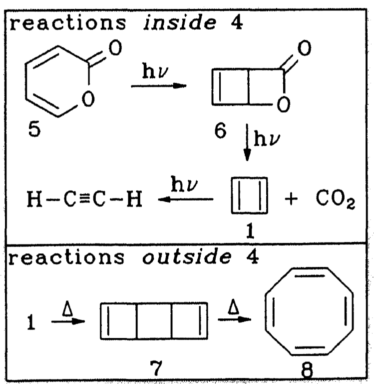



***Figure 3** Reactions inside and outside carcerand (4).*

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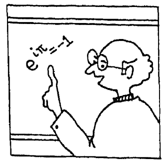


*In this section of* Resonance, *we invite readers to pose questions likely to be raised in a classroom situation. We may suggest strategies for dealing with them, or invite responses, or both. "Classroom" is equally a forum for raising broader issues and sharing personal experiences and viewpoints on matters related to teaching and learning science.*

**? In introducing the Bohr theory of the hydrogen atom, one makes a postulate that electrons in certain special orbits around the centre do not radiate. How does one reconcile this with what students have already learnt about radiation?**

---

From G Venkatesh, Hindustan Academy of Engineering and Applied Science, Bangalore.

**? As an example of special relativity in action, one quotes the case of the muon, with a half-life of less than ten nanoseconds (1 nanosecond = $10^{-9}$ sec). Travelling at almost the speed of light, it should only be able to cover a few metres in this time. But cosmic ray physicists are able to detect muons which have travelled several kilometres, from the top of the atmosphere. Is this an example of length contraction or time dilation?**

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**? How does one find out the molecular/empirical formula of an organic compound?**

From Uday Maitra, Department of Organic Chemistry, Indian Institute of Science, Bangalore.

We are taught even at the high school level the significance of molecular and empirical formulae of molecules. It is therefore important to know how the relative compositions of carbon, hydrogen and nitrogen (the three most common elements in an organic compound, besides oxygen) are experimentally obtained.

Interestingly, the analysis is usually done by *burning* the com-

pound, after carefully purifying it! If you burn any organic compound in excess oxygen, the carbon and hydrogen contents get converted to $CO_2$ and $H_2O$, respectively. If the amounts of $CO_2$ and $H_2O$ obtained from a given weight of the compound can be estimated (by absorbing these two gases in appropriate absorbents), then %C and %H can be easily calculated. The estimation of nitrogen is more involved, and there are classical methods like Kjeldahl's method[1] for determining organic nitrogen. Before the advent of automated analyzers, these methods were followed extensively for the determination of elemental compositions.

[1] Use of Kjeldahl's method is a standard experiment in the M.Sc. programme in many universities.

In modern C/H/N analyzers, the entire operation is automated, and C, H and N percentages can be determined in as little as 10 minutes! The principle here is basically the same, except for N analysis. A known weight of the sample (which may even be one milligram!) is burnt in an excess of oxygen (at about 1000°C) in the presence of oxidizing agents and catalysts. Carbon, hydrogen and nitrogen in the organic compound produce $CO_2$, $H_2O$, and a mixture of nitrogen oxides, respectively. This mixture is then passed over heated (650°C) copper metal, thereby reducing the nitrogen oxides to elemental nitrogen. The mixture of $CO_2$, $H_2O$ and $N_2$ is then passed through a 'Gas Chromatograph',[2] which separates and detects the three gases passing through a thermal conductivity detector. The output from the GC shows three peaks. In order to properly calibrate them, a known weight of a known compound (such as 2,4- dinitrophenylhydrazine) is also analyzed under identical conditions. Therefore, the GC signals coming from the known compound can be utilized for calibrating the peak areas. Thus the areas under the peaks for the unknown sample can be attributed to certain quantities of the three gases.

[2] The details of a 'Gas Chromatograph' will be discussed in a future issue.

In practice, this whole operation is automated, and a computer processes all these data. It may be interesting to know that in many machines twenty different samples can be analyzed automatically, one after the other! Of course, this convenience does not come cheap. Modern C/H/N analyzers can cost as much as Rs.

10 lakhs, and require special chemicals and accessories for their routine operation. Despite the cost, however, these machines are extremely useful for routine analysis of new organic compounds.

It is appropriate to mention here that a mass spectrometer can also give you the molecular weight, and in some cases (under high resolution) the molecular formula as well. However, it does not give any idea about the purity of a sample. On the other hand, the correct composition of a compound of known molecular formula can always be used as a criterion of sample purity.

## ? Given a choice of career, what would you like to be?

A contribution from Milind Watve of M E Society, Abasaheb Garware College, Pune. The original manuscript was titled "On Being a Teacher".

For the last fifteen years, since I became a teacher, I have been conducting personal interviews of all final year students and this is invariably one of the questions. Altogether my sample size must be 900 or so. Only one out of the 900 student said : "A teacher, maybe at a primary school, but I won't mind a high-school or even college".

That reminds me. One of my professors had asked me almost the same question. "What do you plan after your Ph.D?"

This, I think was just casual and personal. Unlike me he didn't seem to be surveying.

"Back to teaching".

"Really ?"

The "really" had all the shades of disbelief, amusement and an exclamation, "After doing a Ph.D in IISc, people talk of going abroad, my son!"

"Well, I would go back to teaching, no doubt, but I might shift from undergraduate teaching ....."

"Oh, to the university ! That will be good".

"No, I mean, given a decent chance, I might shift to school teaching."

I certainly find teaching a very exciting, interesting and challenging job. But I think I belong to a rare species. Few people take to teaching by choice. Those who do, are discouraged by a large number of environmental factors acting against them. Teachers who love teaching even after 8-10 years on the job are likely to do so all their lives. And they constitute the really endangered species.

I often wonder why it is so, when there are several obvious advantages of being a teacher, particularly a science teacher in a college. For one, science teaching involves a constant interaction and what can be more absorbing than that? Teaching at the undergraduate level is an enjoyable exercise, and teaching at high school is even more so. Younger students are more open minded and, given a chance, interact so well with the teacher that the teacher emerges a hundred fold more enlightened. I have a few research papers to my credit and the central ideas in a couple of them have flashed to me in the classroom. Apart from obvious intellectual advantages, being in the company of young minds also keeps you fresh and young. And most of all, you get plenty of free time. For those who decide not to work, there is practically no work; for those who wish to work there is no upper limit. By the way, I have enjoyed both the extremes!

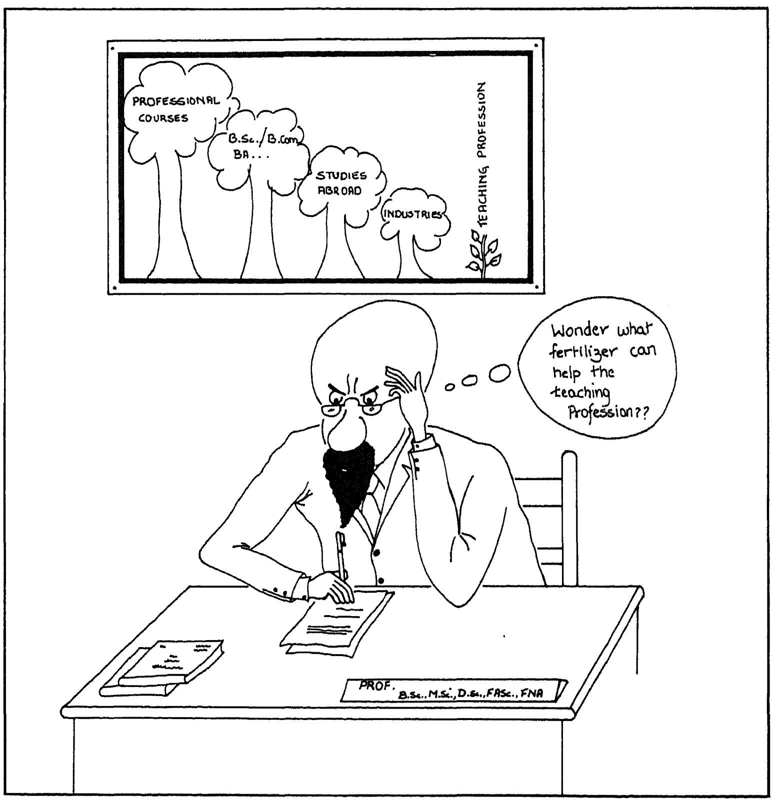
**Teachers who love teaching even after 8-10 years on the job are likely to do so all their lives. And they constitute the really endangered species.**

But none of these benefits seem to attract talented youth. After the +2 level in science, the most successful take professional courses. The sediment comes to B.Sc., after which a talented group opts for management and other professional courses open to them. The next choice is a Masters degree course. After the Masters degree a small but willing fraction gets an opportunity in industries. Those who can manage GRE go abroad and those who survive CSIR tests take to research in India. This leaves us with the last

fragment who come to teaching by default.

Who is to be blamed for this state of affairs? Most probably the teachers themselves. The profession to which the student community has maximum exposure is teaching. And teachers have failed to make a good impact. The major attractions of any profession are prestige and money. There is little prestige in teaching but the money is not too bad. Indeed, compared to the work input required the money is very good. But day by day, other jobs and business opportunities have started paying better, and therefore have become more attractive.

One would certainly find a number of candidates for whom the intellectual challenge is a sufficient motive. Unfortunately this group finds much stagnation in this career. Teaching is largely ritualized and both students as well as college or university




M HARRY WILLIAM

managements expect a teacher to become just another participant in the ritual. Whether or not a teacher maintains a roll call is taken to be more important than whether or not a teacher actually teaches. New ideas, different attitudes or unconventional teaching methods are seldom tolerated. This is most disheartening to anyone who comes in with enthusiasm, claims originality and attempts innovation.

As a result we have entered a vicious cycle. Since teachers have failed to make a good impression about their profession, talented youngsters are not drawn to it. This leaves the teaching community impoverished. From what I can recall when I was a student, the picture was no better. We only had a couple of good teachers; (incidentally one of them took early retirement and the other bid goodbye to teaching). There were many good personalities, no doubt. But being a good teacher is probably more difficult. I won't attempt a formal definition of a good teacher. As a student, I had a very simple measure. One who would keep the attention and interest of a student, no matter how bad, was a good teacher.

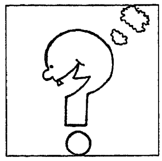
**We need to take a radical new look at teaching itself and science teaching in particular. This is not possible until we have a substantial number of innovative minds in the teaching community and they are encouraged.**

We need to take a radical new look at teaching itself and science teaching in particular. This is not possible until we have a substantial number of innovative minds in the teaching community and they are encouraged. We certainly need to attract talented young graduates to the teaching profession as an indispensable part of any educational policy. But the present picture is grim. A brief look at the interviews of students in the merit list of the SSLC's every year makes it evident. They want to be anything and everything but teachers.

But I haven't lost hope. When I asked the only student who wanted to be a teacher why she was inclined to being one, pat came the answer: "I have seen very few good teachers (does that include me? I dare not ask), and that makes me think it must be challenging!"

And that is the only ray of hope.

# Think It Over



*This section of* Resonance *is meant to raise thought-provoking, interesting, or just plain brain-teasing questions every month, and discuss answers a few months later. Readers are welcome to send in suggestions for such questions, solutions to questions already posed, comments on the solutions discussed in the journal, etc. to* Resonance, *Indian Academy of Sciences, Bangalore 560 080, with "Think It Over" written on the cover or card to help us sort the correspondence. Due to limitations of space, it may not be possible to use all the material received. However, the coordinators of this section (currently A Sitaram and R Nityananda) will try and select items which best illustrate various ideas and concepts, for inclusion in this section.*

## 1 The Population Explosion

Each one of us has two parents. Each one of them has two parents. Going back ten generations, we seem to acquire a respectably large number of ancestors, $2^{10} = 1024$. But go back forty generations, only a little more than a thousand years ago and hence well within historical times, and we calculate $2^{40}$ which is approximately $10^{12}$. This number is comfortably more than the current population of the globe! One immediate reaction is that all these people did not live at the same time. But one only needs to go back a few more generations to make the number large enough. Another reaction one hears is that these people did not have only one descendant, but many. While that is true, one can see that by counting the ancestors of just one person, one has if anything underestimated the population at earlier times. The question therefore is, "Is the real population explosion developing in the past?" We all know that the answer is "no", so what is wrong with the reasoning?

**"Is the real population explosion developing in the past?". We all know that the answer is no, so what is wrong with the reasoning?**

## 2 A Question of Weight.

A large closed box contains air at room temperature and atmospheric pressure, and a bird. The whole box hangs from a spring balance. How is the measured weight of the box affected if the bird

- just sits at the bottom of the box?
- flies?
- stops flying and starts falling downwards?
- falls at the terminal velocity?
- hits the bottom of the box?

What is the effect of (a) having the box open on the sides, with the roof supported by narrow pillars? (b) replacing the bird by a fish and air by water?

## 3 All About Amino Acids

From J Chandrasekhar and Uday Maitra

Test your knowledge of amino acids which occur in proteins ('coded amino acids'). Answers can be deduced from the accompanying poster.

1 How many of the amino acids are chiral?
2 All chiral amino acids have the *L* configuration; however, in the *R/S* nomenclature only one has the *R* configuration. Which one, and why?
3 Which amino acids have more than one asymmetric centre?
4 What are the two common letter-code systems used to represent amino acid residues?
5 What is the ionization form of an amino acid at neutral pH?
6 How many amino acids have aliphatic (hydrocarbon) sidechains?
7 Which amino acids have basic sidechains?
8 Which amino acid sidechains contain a carboxylic acid group?

9 Which amino acids have a hydroxyl group in the sidechain?

10 Which amino acids contain sulphur in the sidechain?

11 Which is the only *imino* acid which occurs in proteins?

12 Aromatic groups an be detected by UV absorption. How many amino acids can be detected by UV?

13 How many amino acids have ionizable sidechains?

14 Which basic sidechain exists predominantly in the unprotonated form at neutral pH?

15 Some amino acids occur both in the acid (COOH) and the amide ($CONH_2$) forms? What are they?

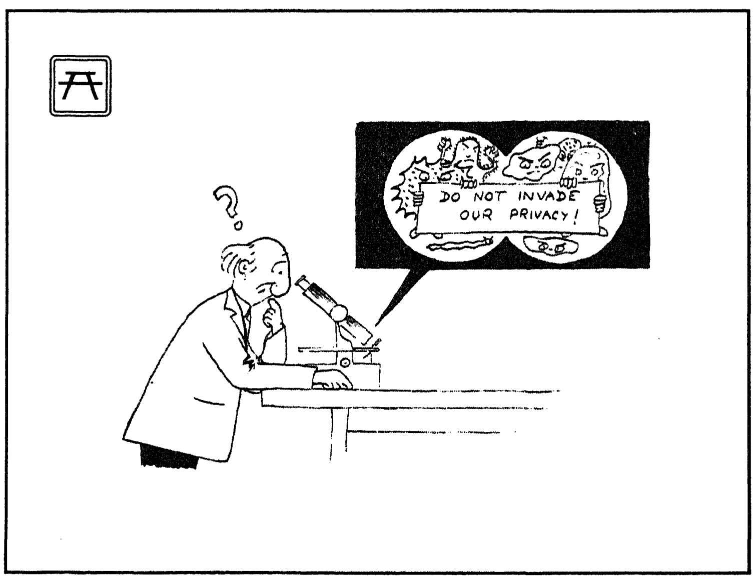
16 Hydrophobic amino acids are usually found in the interior of a protein. Which amino acids are hydrophobic (*Hint*: look for non-polar sidechains)?

17 Which amino acid sidechains are hydrophilic?

18 Disulphide bonds in proteins cross-link two segments. Which amino acid is responsible for this?

19 Normally an amide (RCO-NHR') group adopts a *trans* conformation. There is one amino acid which can lead to both *trans* and *cis* peptide bonds (this leads to bends in the peptide chain). Which one?

20 Which is the most abundant amino acid in *E. coli* proteins?




MOHAN DEVADAS

# Ring of Three Gallium Atoms Displays Aromatic Character

## Another Feather in Hückel's Cap

*Photon Rao*

The simple Hückel rule, which states that conjugated cyclic systems having $4n + 2\ \pi$ electrons ($n$ being an integer) are aromatic, is one of those rules which have really stood the test of time. Many familiar organic molecules and ions can be cited to illustrate the rule. For example, the most elementary aromatic system is a $2\ \pi$ electron system ($n = 0$) and its carbocyclic analogue is the triphenylcyclopropenium cation. Is there an inorganic species which shows similar aromaticity?

Recently, X -W Li, W T Pennington and G H Robinson at Clemson University, USA, have prepared, for the first time, a three membered metallic ring that is isoelectronic with the above mentioned cation *(J. Am. Chem. Soc.,* **117**, *7578, 1995)*. The ring consists of three gallium atoms, each substituted with 2,6-dimesitylphenyl group *(Figure 1)*. Attachment of such bulky groups close to a reactive site is an old ploy used by chemists to tame molecules which are *kinetically* unstable.[1]

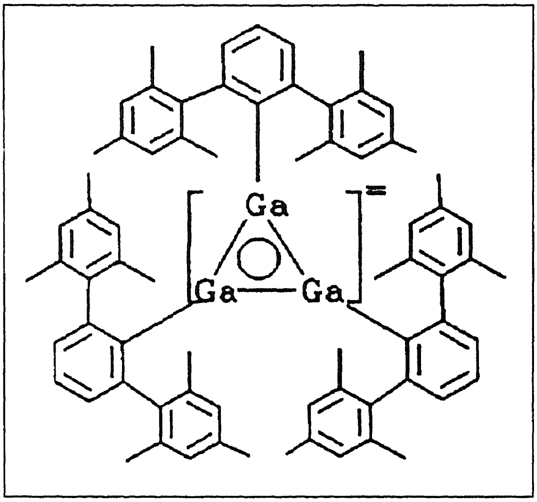



*Figure 1 The three membered metallic ring prepared at Clemson University, USA.*

The actual synthesis involves the cyclotrimerisation of 2,6-dimesitylphenylgallium dichloride using sodium. Even after coupling, two sodium atoms are perfectly centered above and below the $Ga_3$ ring. The structure can be represented as a dianion ring, with $Na^+$ counter-ions. The trivalent gallium atoms are $sp^2$ hybridised and the ring consists of $2\pi$ electrons. The ring is therefore expected to be aromatic. Consistent with this electronic structure, the Ga-Ga bond length of this molecule (2.44 Å) is among the shortest known (for example, the Ga-Ga bond length in $Ga_4[C(SiMe_3)_3]_4$ is 2.69 Å).

[1] Kinetically unstable species are not necessarily high energy species. It just means that the activation barriers for their decomposition pathways are low.

**Photon Rao is an Integrated Ph.D. student in the Department of Organic Chemistry at the Indian Institute of Science, Bangalore 560 012. His major interest is in doing chemistry with big molecules.**

# Clash of the Titans

## What Happens When the DNA and RNA Polymerases Collide

*Sanjeev Galande*

Soon after the discovery of the structure of DNA, it was suggested that the flow of genetic information is unidirectional and that DNA serves as a template for making RNA molecules, which are subsequently used as templates for assembling proteins. This pathway for the flow of genetic information was referred to as the 'central dogma' of molecular biology. Barring a few exceptions where this flow of information is reversed, the central dogma has retained its validity. Its most important feature is that each of these molecules requires a template for its synthesis. Thus, DNA acts as its own template and therefore self replicates, and all RNA molecules are synthesized on DNA templates. Both these processes take advantage of base complementarity; a feature that is central to the structure of DNA and RNA. All proteins are determined by RNA templates by employing a universal code called the genetic code. For survival of a species it is essential that the genetic information is utilised in an accurate manner and therefore nature has evolved distinct machineries for the faithful copying of all these templates into their corresponding products.

The process of copying DNA is called DNA replication, and is carried out by an enzyme called DNA polymerase. The process of copying DNA into RNA is referred to as transcription, and is mediated by a multi-subunit enzyme called RNA polymerase. The DNA and RNA polymerases together with a battery of accessory proteins, constitute the respective copying machinery. The fact that both the replication and transcription machineries utilise the same DNA template poses some mechanistic problems for the cell.

During the process of replication and transcription, the polymerases bind to DNA and start assembling the appropriate building blocks while sliding across the template molecule. The diameter of the polymerase enzymes and their accessory proteins is several times larger than that of double-stranded DNA. Since the process of synthesis of new RNA or DNA molecules involves tracking of such gigantic molecular complexes ('titans'), the management of their intracellular traffic is an important issue for the cell. During this sliding act both the polymerases may use the same DNA single strand as a template, a process referred to as co-directional replication and transcription, or, they may use alternate strands and move in opposite directions. In *Escherichia coli* for example, the rate of replication is known to be 10-15 times faster than the rate of transcription. Thus, irrespective of whether the two polymerases move in the same or opposite directions, collisions between them are inevitable.

Bruce Alberts and his research team at the University of California, Berkeley have been

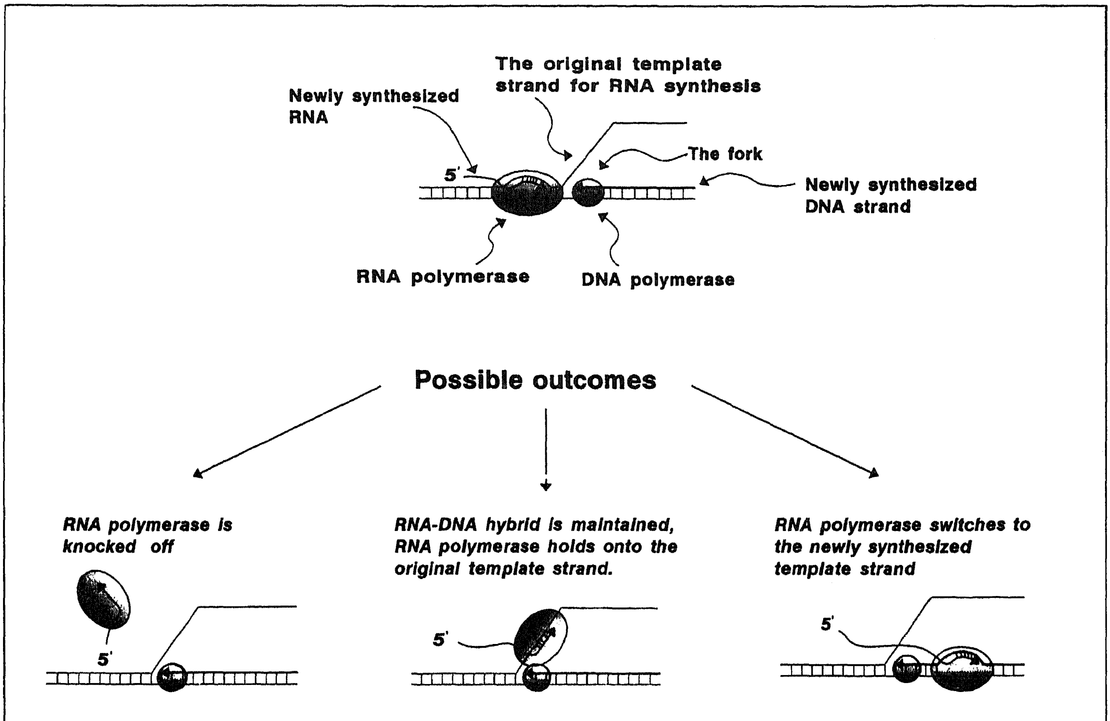



***Figure 1** The possible outcomes following a head-on collision between DNA polymerase and RNA polymerase.*

studying co-directional collisions and have demonstrated that the replication machinery can overtake the transcribing RNA polymerase without displacing it. They mimicked the situation inside the cell by mixing, in a test tube, purified components of the replication and transcription machinery of the bacteriophage T4, a virus that infects *E.coli*.

In a recent article which appeared in *Science* (Vol. 267, 1131-1137, 1995), Bin Liu and Bruce Alberts examined the consequences of a head-on collision between RNA and DNA polymerases trafficking on the same strand of DNA in opposite orientations *(see Figure 1)*. The authors found that the movement of the replication machinery is impeded for a long time when DNA helicase, an enzyme that separates the two strands of DNA, is absent. However, addition of DNA helicase (which is a normal component of the replication apparatus of the cell) allowed the replication machinery to bypass the transcription machinery after a brief pause. As a consequence of such a bypass, the transcription machinery switched its template DNA strand and began to utilize the newly synthesized DNA strand. To get a better idea one may imagine a situation where one passenger train is compelled to change over to another track in order to avoid collision with a superfast express train approaching from the opposite direction (some-

thing that unfortunately does not always happen!) It should be noted however that such switching of the template strand by the RNA polymerase requires some extra energy to be spent by the cell. It therefore appears that a head on collision is more expensive for the cell than a co-directional collision.

Hence, the cells appear to have evolved a strategy by which these highly efficient copying machineries have some degree of flexibility in switching template strands. Since a co-directional collision between RNA and DNA polymerases is more energy efficient than a head-on collision, the genetic material of several prokaryotes such as bacteria and viruses is organised in a manner which ensures that most of the frequently transcribed genes are oriented in the direction of the replication fork movement. The clash between the "Titans" being inevitable, cells have to chosen the least harmful way to deal with it. The genetic material of eukaryotes is quite complex and its sheer size makes the understanding of such processes a daunting task. At this moment one can simply hypothesize that since the eukaryotic replication and transcription machineries share common structural organisations with their prokaryotic counterparts, what is good for *E.coli* may also hold good for an elephant!

**Sanjeev Galande is a research scholar at the Department of Biochemistry, Indian Institute of Science, Bangalore.**

# Discovery of the Top Quark

## Missing Member of the Family Traced

***R Ramachandran***

All matter in the universe is believed to be made up of quarks (which are subconstituents of protons, neutrons, mesons, etc.) and leptons (such as electrons and neutrinos). The dynamics of these quarks and leptons which lead to electromagnetic, weak radioactive and strong nuclear forces are governed by laws which are a generalized form of Maxwell's laws of electromagnetism.

Most matter exists as molecules and atoms. Atoms consist of compact nuclei containing protons and neutrons held together by nuclear forces, and negatively charged electrons which are bound electrically to these nuclei. High-energy scattering experiments enable us to see if

**Our universe consists mostly of the 'up' and 'down' quarks and the electron and electron neutrino.**

protons and neutrons have a substructure. Indeed experiments involving high-energy inelastic scattering of electrons (or muons) reveal that nucleons (protons and neutrons) are bound states of two species of quarks, gener-

**By the 1970's it became clear that there is a second family of quarks and leptons: the 'charm' and 'strange' quarks and the muon and muon neutrino.**

ally referred to as the 'up' and 'down' quarks. Roughly speaking, a proton is composed of two 'up' ($u$) quarks and one 'down' ($d$) quark. Since $u$ quarks carry 2/3 units of electric charge (the unit is chosen so that electrons have a charge of −1) and $d$ quarks carry −1/3 charge, protons have one unit of charge. Neutrons, on the contrary, are neutral and are made up of one $u$ and two $d$ quarks. There is a symmetry called isospin which places the pair of nucleons, i.e. protons and neutrons, on a similar footing. (This is analogous to the two possible states of a spin 1/2 system). At a deeper level, the isospin symmetry can be traced to a similar relationship between the $u$ and $d$ quarks. Note that there is a difference of one unit of charge between the $u$ and $d$ quarks forming the isospin doublet. To this pair, we may add a lepton doublet consisting of an electron neutrino ($\nu_e$ with 0 charge) and an electron ($e^-$ with −1 charge). Our universe consists mostly of ($u$, $d$) quarks and ($\nu_e$, $e^-$) leptons.

By the seventies, it became clear that there are more species of quarks and leptons. For instance, there is the muon $\mu^-$, with properties similar to the electron, but about 207 times more massive. There is a neutrino $\nu_\mu$ which goes with it. Further, there are two other quarks which are picturesquely referred to as the 'strange' quark ($s$ with −1/3 charge) and the 'charm' quark ($c$ with 2/3 charge). So we add the ($c$, $s$) quarks and the ($\nu_\mu$, $\mu^-$) leptons to our collection of elementary particles. The nucleons have a mass* of about 0.94 GeV/c$^2$ while electrons have a mass of 0.51 MeV/c$^2$. Neutrinos are believed to be either strictly massless or have very tiny masses, while the $s$ and $c$ quarks are more massive than the $u$ and $d$ quarks. It is a bit difficult to talk about the masses of the quarks since free quarks are never seen. (It is believed that quarks are permanently confined within a strongly interacting particle such as a nucleon). Nevertheless, it is possible to estimate 1/3 GeV/c$^2$ as being the approximate effective mass for the $u$ and $d$ quarks, 1/2 GeV/c$^2$ for the $s$ quark, and nearly 1.5 GeV/c$^2$ for the $c$ quark. The first indication of the $c$ quark was a bound state $c\bar{c}$ (made out of a $c$ quark and its antiparticle $\bar{c}$) with a mass of about 3.1 GeV/c$^2$ which was

**In 1975 the discovery of the tau lepton indicated the existence of a third family of quarks and leptons. The tau neutrino was inferred and the 'bottom' quark was seen soon after, and the quest for the missing 'top' quark began in right earnest.**

* MeV, GeV and TeV denote energies equal to $10^6$, $10^9$ and $10^{12}$ electron volts respectively. The masses of elementary particles are often quoted in units of energy/c$^2$ following Einstein's famous equation $E = mc^2$ where $c$ denotes the speed of light. 1 GeV/c$^2$ corresponds to a mass of about $1.78 \times 10^{-27}$ kg.

**The Basic Constituents of Matter**

These consist of six quarks and six leptons. They are listed below in three families, with their charges. The recent discovery of the 'top' quark ($t$) is important because it completes this list of quarks.

| Charge | Leptons −1 | Leptons 0 | Quarks 2/3 | Quarks −1/3 |
|---|---|---|---|---|
| Family 1 | electron $e$ | electron neutrino $\nu_e$ | 'up' quark $u$ | 'down' quark $d$ |
| Family 2 | muon $\mu$ | muon neutrino $\nu_\mu$ | 'charmed' quark $c$ | 'strange' quark $s$ |
| Family 3 | tau $\tau$ | tau neutrino $\nu_\tau$ | 'top' quark $t$ | 'bottom' quark $b$ |

*($\nu_\tau$ has not yet been directly detected)*

observed at Stanford in 1974 in positron-electron ($e^+e^-$) collisions. This was confirmed at Brookhaven soon afterwards in proton-proton collision experiments.

In the late seventies, there was an indication that there could be one more set of quarks and leptons. The first to be discovered, in 1975, was the heavier brother (sister?) of the electron and the muon. The $\tau$ lepton has a mass of 1.784 GeV/c$^2$ and there is a related neutrino $\nu_\tau$. We can expect this lepton doublet to be accompanied by a quark doublet. In 1977, a new quark called 'bottom' ($b$) was seen in the bound state $b\bar{b}$ in $e^+e^-$ collisions at about 10 GeV total energy. The $b$ quark has −1/3 charge. Naturally the quest began for its partner quark called 'top' ($t$) which should have 2/3 charge. This doublet ($t$, $b$) would then form the third generation of quarks. (The discoverers of the neutrino and $\tau$, Reines and Perl, were awarded the Nobel Prize for physics in 1995).

We need high-energy projectiles to be able to produce the heavy 'top' quark. In fact, there was no clue as to how massive the $t$ quark would be. With the commissioning of each new high energy accelerator, attempts were made to scan through the available energy range for a possible sighting of the $t$ quark. And as the $t$ quark remained elusive, the lower limit for its mass kept going up. Further, since there are many channels for scattering reactions at high energies, searching for the $t$ quark signal was like looking for a needle in a haystack — a laborious and complicated process. A faint clue came from another important experiment. The precision measurements

on the $Z$ bosons, which were copiously produced at the Large Electron Positron (LEP) collider at CERN, Geneva, suggested a possible range for the $t$ quark mass in the interval 150-200 GeV/$c^2$. The final proof came in the experiments done in the last two years at Fermilab near Chicago in the Tevatron collider (so named because this machine can reach a total energy of 1 TeV). In the Tevatron, protons and antiprotons of total energy 900 GeV collide to produce various kinds of states which are then analysed by two gigantic detector systems called D0 (D zero) and CDF (Collider Detector Facility). Each system is operated by a team of about 400 physicists from about 40 laboratories in the world (D0 includes TIFR, Panjab and Delhi Universities). Both experimental groups have now announced that they see candidate events which can be regarded as observations of the $t$ quark. Typically, the bound state $t\bar{t}$ which is produced decays yielding $W^+ W^- b\bar{b}$. (The $W^+ W^-$ and $Z$ bosons are the carriers of the weak interactions just as the photon is the carrier of the electromagnetic interactions among quarks and leptons). The strategy for detection was to look for events when both the $W$ particles decay giving rise to $ee^+$ jets, $e\mu^+$ jets and $\mu\mu^+$ jets, or when one of the $W$'s decays producing $e^+$ jets and $\mu^+$ jets. The jets are produced by the $b$ quark and by the subsequent chain of heavy quarks which result from successive decays. The D0 team reports 17 candidate events with an expected background (noise) of 3.8 $\pm$ 0.6 events. The mass of the $t$ quark is measured to be 199 $\pm$ 20 (stat) $\pm$ 22 (syst) GeV/$c^2$, the uncertainties arising from possible statistical and systematic errors. The CDF group finds the $t$ quark mass to be 176$\pm$8 (stat) $\pm$10 (syst) GeV/$c^2$.

**Searching for the 'top' quark signal was like looking for a needle in the haystack. But experiments carried out at the Tevatron collider at Fermilab in 1994-95 now provide the final proof of the existence of the 'top' quark.**

With this observation, we seem to have three generations of quarks and leptons. Independently, by studying the life-time of the $Z$ boson, we can deduce the number of species of neutrinos into which $Z$ can decay. The result of the analysis strongly suggests that the number of generations (with one species of $\nu$ for each generation) is just three. Perhaps there are no more quarks or leptons to be discovered. The 'top' may be the last elementary particle.

While the 'top' discovery filled the missing piece in the set of basic constituents of matter, it has also raised many questions. For instance, why is 'top' so much heavier than the other quarks? This makes the 'top' quark extremely 'short lived' and throws up new puzzles to be solved. Further research is needed to understand the properties that 'top' shares with other quarks and the ways in which it is different from them.

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# Factoring Fermat Numbers

## A Unique Computational Experiment for Factoring $F_9$

*C E Veni Madhavan*

Fermat observed that the numbers $F_k = 2^{2^k} + 1$, $k = 0, 1, 2, 3, 4$ are prime, and wondered whether this was true for all $k$. Euler found that the very next Fermat number is composite: $F_5 = 2^{32} + 1 = 641 * 6700417$. So far it has been verified that $F_k$, $5 \leq k \leq 22$ are all *composite*. No one knows whether any other $F_k$ is prime. The numbers $F_k$ grow rapidly with $k$ — each is almost a square of the previous number — and it is a very difficult task to decide their primality. We give below an outline of the relevant computational challenges.

First note that, if $k$ is odd, 3 divides $2^k + 1$ and in general, $2^a + 1$ divides $2^{ak} + 1$. Thus, if $k$ is not a power of two, $2^k + 1$ is not prime. Fermat hazarded a guess that the converse was also true. In 1877, François Pépin published a necessary and sufficient condition which states that $F_k$, $k > 1$ is prime if and only if $F_k$ divides $5^{(F_k - 1)/2} + 1$. This condition is the basis for determining whether $F_k$ is prime for any given $k$. Failure of this condition means that $F_k$ is composite. It does not reveal any information about the factors.

Today, sophisticated number theoretic methods and powerful computing platforms are used for testing primality and factoring of large integers. These find applications in many practical problems such as cryptography. The recent records in Fermat number factoring have been achieved by means of two techniques called *number field sieve* (NFS) and *elliptic curve method* (ECM).

The complete factoring of $F_9$, which has about 150 decimal digits was carried out in 1992 by a unique computational experiment. Hundreds of computers in different parts of the world, working independently and in their spare time generated certain seed numbers. These computers sent their seeds by electronic mail to a host computer in USA. The host carried out the combination of the seeds and the factoring. The NFS method, requiring the generation of an enormous number of such seeds, was thus eminently suitable for this exercise. However this method is quite difficult to implement.

Last year the number $F_{22}$ was determined to be composite, using Pépin's criterion and extremely fast arithmetical algorithms implemented on supercomputers. This number of about 1.3 million decimal digits (about 500 times as long as this article) required about $10^{16}$ arithmetical operations and about seven months of real time. Complete factorization of Fermat numbers is known only for $k \leq 9$ and $k = 11$. No prime factors of $F_{14}$ and $F_{20}$ are known.

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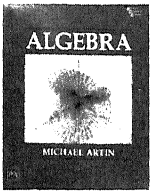
# Algebra for Everyone

## A Beautiful Book at an Affordable Price

*Kapil H Paranjape, Dilip P Patil*




*Algebra*
M Artin
Prentice-Hall of India Private Limited,
New Delhi. 1994
pp. 618. Rs.150.

In primary school we learn how to perform the operations of addition and multiplication with natural (or counting) numbers. We then learn how to include the negative numbers to perform subtractions and fractions to perform divisions. Later in high school we learn to use variables *as if* these were numbers and perform operations on them. Soon after, we learn elementary operations on matrices and discover the possibility that multiplication may not be commutative (i.e., *AB need not be equal to BA*). The study of these basic entities and operations lies at the foundation of modern algebra.

The natural question that arises is: When can we extend the operations and work *as if* we are dealing with the familiar number system? A well-known warning in school is "do not divide by zero" — can one always divide by a non-zero entity or equivalently what can one divide by? Another pitfall is the one indicated above: that matrices do not commute. Modern algebra formalises the rules necessary to deal with operations that are *like* addition, subtraction, division and multiplication in such a manner as to avoid similar traps. A number of beautiful (and sometimes unexpected) applications to other areas result — since we can now recognise the familiar operations in a number of different disguises.

**We have here not so much an algebraist's algebra book but one for a more general mathematical training.**

A pure algebraist would thus be quite content to study the general *formal* theory with examples introduced only to show why some results cannot be stated in greater generality (—most algebraists are not so pure however!). The book under review has taken an approach almost opposite to this. All topics and definitions are introduced with examples to show how these work. In that sense we have here not so much an algebraist's algebra book but one for a more general mathematical training (which is not to say a budding algebraist will not benefit from reading it!). In fact one could go so far as to say that the material in this book is essential for any person wishing to use any kind of mathematics. A more detailed account of the material in this book follows.

The first four chapters deal with the elements of matrices, groups, vector spaces and linear transformations. Chapter 4 has some nice applications to systems of linear differential equations. Chapter 5 has beautiful discussions on symmetries of plane figures, groups of motions of the plane, discrete groups of motions,

abstract symmetry etc. It is unusual to find this kind of material presented so well in a book at this level. Chapter 6 continues with more group theory and ends with a section on the Todd-Coxeter Algorithm, again a topic not usually found in a book at this level. Chapter 7 deals with bilinear forms, hermitian forms, spectral theorem etc. An introduction to linear groups and group representations is attractively presented in Chapters 8 and 9. The notion of the Lie algebra of a linear group is discussed in Chapter 8. These two chapters can be used at the M.Sc. first year level to give an introductory course on Lie groups and group representations. Chapter 10, which is mainly a chapter on rings and ideals has a concluding section providing a nice motivation for the study of algebraic geometry. The chapter on factorization, Chapter 11, has a detailed discussion on the arithmetic of quadratic number fields, again a topic not normally found in an introductory text book. Chapter 12 is on modules leading to applications to the structure theorem for abelian groups and various canonical forms for linear operators. Chapters 13 and 14 provide an excellent introduction to field theory including Galois theory.

This book can be used as a text at the undergraduate as well as the M.Sc. levels. *A Note for the Teacher* included in the beginning of the book gives several useful suggestions for developing various courses based on it. There are plenty of excellent exercises, the more challenging ones being marked with an asterisk. It is fortunate that this book is now available to Indian students and teachers at an eminently affordable price. No personal collection of a research mathematician, student or teacher will be complete without it!

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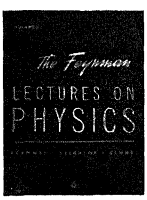
## A Joyous Romp Through Basic Physics

### The Work of a Magician of the Highest Calibre

*V Balakrishnan*




*The Feynman Lectures on Physics, Vol. 1 & 2*
R P Feynman, R B Leighton, M Sands
Addison-Wesley, Reading, Mass., 1963 and Narosa, New Delhi, 1987
pp.550 + 580 Rs.300

Some years ago, this reviewer began an additional preface to the Indian edition of the *Feynman Lectures on Physics (FLP)* with the words, "The Feynman Lectures on Physics rank among the classics of our times, and it borders on impertinence to attempt to write a preface to them". If a preface is impertinence, a review may be lèse-majesté!"But one must try", as Dirac is reported to have told Feynman in connection with the "search for a meson equation" analogous to that discovered by Dirac for the electron. And so:

Richard Feynman (1918-1988) was an American theoretical physicist who shared the Nobel Prize in 1964 with Tomonaga (Japan) and Schwinger (USA) for very basic work on "quantum electrodynamics". This theory describes the interaction of electrons and other charged material particles with photons, i.e. with light. He also made important contributions towards understanding the behaviour of liquid helium and the internal structure of the proton and the neutron. His colourful life and personality and unique style of doing physics have been well documented in James Gleick's book.

Feynman did something very unconventional at the height of his research career. He spent two entire years planning and teaching a course of physics at the undergraduate level (i.e like our BSc. in India). The three volumes which resulted are not a conventional textbook but have inspired generations of physicists. We hope that reviewing them in ***Resonance*** will help a new generation of students and teachers learn about their existence and benefit from their unique view of physics.

*R Nityananda*

How does one describe a set of books whose lively chapters (52 in Vol.1, 42 in Vol.2) represent nothing less than a joyous romp through all of basic physics (and often the relevant mathematics, too) for the interested beginner, and an exuberant celebration of the beautiful edifice called classical physics for the more knowledgeable reader? Like the best wine, these books seem to improve with age — the age of the reader, as well ! Each time one goes back to the FLP, one gains new insights especially in the pedagogy of physics. Instead of merely describing ("reviewing") the contents of the volumes, it might be more interesting to focus on peripheral information that is relevant to the appreciation of this unique legacy of one of the greatest minds of our times.

The whole project began with a plan for a totally revised, up-to-date course in basic physics at Caltech in the early sixties. As in most serious efforts of this kind, detailed and thorough discussions of various suggestions and alternatives took place. The solution arrived at finally was remarkable: to have Richard Feynman (who had never handled freshman physics previously) prepare and deliver a complete set of lectures; and record, transcribe and edit these in the form of a textbook for the proposed new course on physics. This is essentially what was done. Volume 1 covers the lectures given (at the rate of two per week)

**Like the best wine, the Feynman volumes seem to improve with age — the age of the reader, as well ! Each time one goes back to the FLP, one gains new insights especially in the pedagogy of physics.**

during the academic year 1961-62, while Volume 2 covers those given during the bulk of the academic year 1962-63. (Volume 3, on Quantum Mechanics, covers the lectures given during the last quarter of the second year.) Feynman himself states that he would have preferred to have followed up electromagnetism mainly with "...things like fundamental modes, solutions of the diffusion equation, vibrating systems, orthogonal functions, ... developing the first stages of what are usually called the mathematical methods of physics." Given the incomparable combination of physical insight and mathematical ingenuity that Feynman possessed, what might we not have seen if only this had come about!

And yet there is sufficient magic in the volumes that did see the light of day. The great mathematical physicist Mark Kac classified Feynman as “a magician of the highest calibre” in tribute. The wand-waving is delectably in evidence throughout the FLP. Today, more than thirty years after the event, we are witness to a flurry of recognition of Feynman’s heroic effort, by way of various new editions, video cassettes, and so on. Feynman himself worked extremely hard on these lectures (and the demonstrations that accompanied them). “He gave 100 per cent of his time to these lectures. He worked from eight to sixteen hours per day on these lectures, thinking through his own outline and planning how each lecture fitted with the other parts”. If the lectures themselves constituted a two-year long virtuoso performance, no less strenuous was the job of converting them into the classic printed version we now have — a task “that required the close attention of professional physicists (Richard Leighton, Matthew Sands) for ten to twenty hours per lecture!”. Great care was taken however, to preserve the style and spirit of the lectures — the informal language, the zestful progression to real explanations and the lively ‘Aha’ of discovery. (“The understanding was reached that the publisher would follow the manuscripts that were provided — because it was not a textbook but a book of lectures.”)

**Robert Walker told Feynman: "Some day you will realize that what you did for physics in those two years is far more important than any research you could have done during the same period."**

What did Feynman himself think of the FLP? Some brief comments are to be found in Feynman’s own preface to the FLP, but he said more in retrospect, less than a month before he passed away: "Now if you ask me if I think I succeeded in teaching physics well, I haven’t the slightest idea....At the end of two years (1961-63) I felt that I had wasted two years, that I had done no research during this entire period...I remember Robert Walker saying to me: 'Some day you will realize that what you did for physics in those two years is far more important than any research you could have done during the same period'. I said, 'You’re crazy!'. I don’t think he’s crazy now. I

think he was right...when I read them (the FLP) over, ....they're good, they're all right. I'm satisfied; rather, I'm not dissatisfied with them...I must admit now that I cannot deny that they are really a contribution to the physics world."

There isn't a whiff of overstatement here. Over the past fifty years, if not more, dedicated and experienced teachers, researchers and educationists have grappled with the problem of successfully teaching basic physics. It is no exaggeration to assert that the problem has unique aspects that are not shared by the problem of teaching other subjects such as mathematics, chemistry or biology at a corresponding level. (These may have other features of their own, but that is not the issue here.) Entire essays could be (and have been) written on these aspects. Some basic ones that readily come to mind are: Our intuition or mind-set (evolutionary hard-wiring?) tends to be 'Aristotelian' (force $\Rightarrow$ change of position), whereas the macroscopic mechanical world is Galilean/Newtonian (force $\Rightarrow$ change of velocity). Physics is quantitative; its laws are inevitably expressed mathematically. Applying them involves a fairly sophisticated three-fold process: a proper translation (by the student) of the physical problem into mathematical terms, its solution using freshly and often incompletely acquired mathematical tools, and finally an interpretation of the mathematical solution back in physical terms. These abilities are not easily acquired, in general. An editorial by John Rigden on the introductory course in physics in the *American Journal of Physics* concludes with the somewhat diffident words:

> "*The students*. They leave the introductory course with a disjointed, collage-like idea as to the content of physics and they leave with no idea whatsoever how it is that we know what we know.
>
> *The faculty*. They leave with a rekindled and deepened awareness of the conceptual richness of the introductory course. They are happy with the way they have brought the ideas together.
>
> *The introductory course...* illusion..."

**There are very few places in the physics literature where one is likely to encounter the calculated aplomb needed to write down just eight lines in a table, and to call it "all of classical physics".**

In this situation, the FLP offer grounds for optimism. A perspective that takes in the twin paradox, the Krebs cycle, seismic waves, insect vision, thunderstorms, crystal dislocations, vorticity and alternating-gradient synchrotrons, among other things, and tells one how to place them in their logical positions on a vast mental tapestry is no mean accomplishment. There are very few places in the physics literature where one is likely to encounter the calculated aplomb needed to write down just eight lines in a table, and to call it "all of classical physics". (The eight lines are: the

four Maxwell equations, the continuity equation, the Lorentz force expression, Newton's second law of motion and the inverse square law of gravitation.) Professional physicists know how uncommon it is for even advanced-level textbooks (as opposed to specialized monographs) to appear as references in papers reporting on current research. How extraordinary, then, must a book at the undergraduate level be to merit numerous such citations? This reviewer can think of at least two different examples of this sort in the FLP. The first is figures 41-6 in Vol.2, captioned "Flow past a cylinder for various Reynolds numbers". Evidently such a clearly delineated set of sketches is not too common even in the specialized hydrodynamical literature! The second is the beautiful little chapter on irreversibility in Vol.1 (Ch.46, entitled 'Ratchet and pawl'). The analysis of the hypothetical device described in this chapter has attracted considerable attention in recent years. These are but a few instances of the remarkable clarity of focus on the real issues, sometimes bordering on prescience, that is characteristic of the FLP. As Feynman himself said in relation to the FLP, "...I've always been trying to improve the method of understanding everything...There was always a certain pleasure in discovering for myself actually that I could understand many more things than I thought I could from the elementary point of view. I would use these explanations (in the lectures)." James Gleick ends his biography of Feynman with the words, "An imprint remained: what he knew; how he knew". *The Feynman Lectures on Physics* are an important and memorable part of that imprint.

### Suggested reading

**R P Feynman. Preface, FLP.**

**M Kac. Enigmas of Chance. Harper & Row, New York. 1985.**

**J Mehra. The Beat of a Different Drum — The Life and Science of Richard Feynman. Clarendon, Oxford. 1993.**

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**R P Feynman in Interviews and Conversations with J. Mehra. 1988. Quoted in Ref.3, Ch.22**

**J S Rigden. *Am. J. Phys.* 52: 303. 1984.**

**J Gleick. Genius — Richard Feynman and Modern Physics. Rupa, Calcutta. 1992.**

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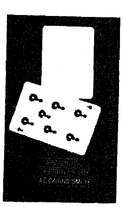
# "Odd, Watson - Very Odd!"

## The Chemical Evolution Model Revisited

***S Mahadevan***



*Seven Clues to the Origin of Life - A Scientific Detective Story*
A G Cairns-Smith
Cambridge University Press, Cambridge, 1985
pp. xii + 131. Rs.195.

The origin of life on earth, as described in most standard text books, has seemingly two contradictory aspects. Most authors start by describing the classic experiments of Redi, Spallanzani and Louis Pasteur that disproved the theory of spontaneous origin of life forms from inanimate matter, leading to the conclusion that life can arise only from pre-existing life. This automatically leads to the question as to how it arose in the first place. Here, one

has to back track and seriously reconsider evolution of life forms from the pre-biotic, i.e. non-living environment. This is taken in stride and the experiments of Miller are described. The ultimate conclusion drawn is that chemical evolution gave us the primitive life forms and biological evolution, mediated by natural selection, gave us the varied life forms seen today. This is accepted today by most biologists, in many cases for want of a better theory.

In this context, Cairns-Smith's extremely readable book, *Seven Clues to the Origin of Life: A Scientific Detective Story* offers a serious re-examination of our ideas of chemical evolution. The book is written for the lay-person with no training in biological sciences. In spite of this, it is fun reading for any one interested in biology, particularly students and teachers, as well as fans of Sherlock Holmes, for the author depends heavily on the methods of the illustrious fictional detective created by Sir Arthur Conan Doyle. Holmes used his powers of logic to solve extremely complex cases. Here, the author uses the same style of arguments to examine our current understanding of the chemical evolution of life.

As the author states in the introductory chapter itself, no one doubts that evolution has occurred. What he questions is the commonly believed role attributed to chemical evolution. As the title suggests, the arguments are presented in the form of seven clues which point to the inadequacies of the chemical evolution model as it is understood conventionally.

The introductory chapter examines the various possible models proposed for the origin of life. Was it the result of natural events or supernatural intervention? Based on available evidence, the likely conclusion is that life originated on earth due to natural causes 3-4 billion years ago. He compares our position to that of Sherlock Holmes starting his famous case of *The Hound of the Baskervilles*. We have to exhaust all other possibilities before falling back on the supernatural. The following chap-

PREMA IYER

**Holmes used his powers of logic to solve extremely complex cases. Here, the author uses the same style of arguments to examine our current understanding of the chemical evolution of life.**

ters take us through our present concepts of information transfer in biological systems and the interrelation between various biological processes. The result of this exercise is the appreciation that biological systems that exist today are extraordinarily complex, consisting of interlocking components that can function only in a mutually dependent manner. Armed with our current knowledge about the molecular architecture of living beings, we can go back to the initial question as to how it all started. In the author's view, the explanation given in terms of chemical evolution is far from satisfactory. After leading us through a garden path initially, the theory leads us to an insurmountable cliff-face.

**The major problem with the chemical evolutionary theory, according to the author, is the fact that it fails to explain the interdependent nature of the different components of the living system. The basic molecular processes such as DNA replication, transcription, and translation are multicomponent systems that are closely tied to each other. It is almost unimaginable that they evolved independently and came together in a miraculous fashion.**

The major problem with the chemical evolutionary theory, according to the author, is the fact that it fails to explain the interdependent nature of the different components of the living system. The basic molecular processes such as DNA replication, transcription, and translation are multicomponent systems that are closely tied to each other. It is almost unimaginable that they evolved independently and came together in a miraculous fashion. It is also equally unlikely that they evolved simultaneously. The problem is similar to building an arch without a scaffolding. The stones of an arch cannot be assembled one at a time without a support as the whole structure will collapse. Similarly, in the absence of a 'scaffold', the interlocking components of the biological system cannot evolve independently. But then, where is the supporting structure? This argument is a bit weak as it applies not only to the molecular aspect of evolution, but also to biological evolution. Therefore, by the same argument,the transformation of a single cell to a complex organism with interacting components is not likely to happen in the absence of a scaffold.

The disparity between the available experimental evidence for the synthesis of organic molecules in the prebiotic soup under harsh geological conditions and the complexity of the final products of evolution, according to the author, is simply too vast and takes a giant leap of imagination to go from one to the other. The organic synthesis of DNA, RNA, and proteins involves dehydration and their synthesis in an aqueous environment is next to impossible in the absence of catalysts. Thus it is difficult to picture the direct evolution of the entire ensemble of biopolymers and the biochemical cycles. These arguments are pre-

sented lucidly in the following chapters.

In the absence of the direct evolution of organic biopolymers from the prebiotic soup, what other possibilities can one consider? The author suggests the clue provided by the rope. The fibres that make the rope need not run through the entire length of the rope as long as they can be interconnected. The same way, newer organisms carrying more efficient genes can be generated sequentially like the fibres of the rope. The rope symbolises the continuum of life forms as they gradually evolved, one giving way to another as new genes were created replacing old ones. (Strangely, ropes found at the scene of crime gave valuable clues to Sherlock Holmes also. At least in two cases, they helped him in the identification of the criminal.)

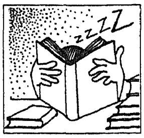
But then where is the scaffolding? Where are the catalysts? Where are the secluded chambers where the primitive information molecules that were evolving could be isolated from the vagaries of the environment? The way the author reads the clues, the answers have to come from inorganic rather than organic molecules. Crystals can be the primitive carriers of information. With their ability for self assembly, they can be reproduced relatively easily. With their layers of closely stacked atoms, they can offer a matrix for chemical reactions, thus playing the role of a primitive catalyst. With polarised surfaces, they can also act as a primitive biomembrane. The primary organisms based on minerals could gradually lead to the formation of secondary organisms based on organic chemicals. Because of their inherent efficiency, they could gradually replace the primary organisms in a genetic takeover. The scaffolding was probably destroyed in the course of time.

**The book is thoroughly readable, as it promotes a healthy irreverence to many closely held beliefs of molecular evolutionists.**

What could be the inorganic molecule that is best suited for such a challenging task ? Well, like any reviewer of detective stories, I do not want to name the 'culprit'. The author's choice is quite original and plausible. However, one gets the feeling of an anticlimax at the end of the book. Expecting an ending similar to the logical manner in which Sherlock Holmes would summarise his case, one is presented with the flair of Hercule Poirot who is known to present his culprits dramatically without sharing with the reader the evidence that led him to his remarkable results. But despite this limitation, the book is thoroughly readable, as it promotes a healthy irreverence to many closely held beliefs of molecular evolutionists. In a culture like ours which takes the printed word as the gospel truth, questioning of "holy cows" is definitely recommended. As Holmes would say, "The game is afoot, Watson!"

**S Mahadevan is with the Developmental Biology and Genetics Laboratory at Indian Institute of Science, Bangalore.**

# Books Received



*Instrumentation And Process Measurements*
W Bolton
Longman Group (UK) Ltd.
Orient Longman Ltd.
1991, Rs.75.

*Industrial Control And Instrumentation*
W Bolton
Longman Group (UK) Ltd.
Orient Longman Ltd.
1991, Rs.100.

*Mathematical Analysis*
Tom M Apostol
Narosa Publishing House
1991, Rs.75.

*Bhabha And His Magnificent Obsessions*
G Venkataraman
Universities Press India Ltd.
Orient Longman Ltd.
1994, Rs.85.

*A Hot Story*
G Venkataraman
Universities Press India Ltd.
Orient Longman Ltd.
1993, Rs.60.

*Chandrasekhar And His Limit*
G Venkataraman
Universities Press India Ltd.
Orient Longman Ltd.
1992, Rs.60.

*The Many Phases Of Matter*
G Venkataraman
Universities Press India Ltd.
Orient Longman Ltd.
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*Why Are Things The Way They are?*
G Venkataraman
Universities Press India Ltd.
Orient Longman Ltd.
1992, Rs.60.

*Raman And His Effect*
G Venkataraman
Universities Press India Ltd.
Orient Longman Ltd.
1995, Rs.55.

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G Venkataraman
Universities Press India Ltd.
Orient Longman Ltd.
1995, Rs.80.

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G Venkataraman
Universities Press India Ltd.
Orient Longman Ltd.
1993, Rs.60.

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G Venkataraman
Universities Press India Ltd.
Orient Longman Ltd.
1992, Rs.60.

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G Venkataraman
Universities Press India Ltd.
Orient Longman Ltd.
1994, Rs.80.

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G Venkataraman
Universities Press India Ltd.
Orient Longman Ltd.
1994, Rs.65.

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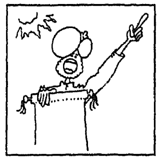
G Venkataraman
Universities Press India Ltd.
Orient Longman Ltd.
1994, Rs.65.

# Information and Announcements



## ia to Host 1996 International Mathematical Olympiad

ill host the 37th International Math-
l Olympiad (IMO) in July 1996 in
elhi. The IMO, which is an annual
; the most celebrated intellectual con-
;chool children all over the world. The
ɜr IMO was held in 1959 in Romania
st seven countries taking part. This
s expected that about 75 countries will
›ate. Each participating country can
:eam of upto six students. To be able to
in the IMO a student must not have
l the university and should be below 20
f age.

ational Board for Higher Mathematics
M) is organizing the event which will be
›red by the Ministry of Human Re-
s Development. The selection of the
. team for the 1996 IMO has already

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ndian team for the IMO is selected during the
camp usually conducted in the month of May
ɜar. The students for these camps are selected
ı the Indian National Mathematical Olympiad
held in February every year. To qualify for the
students have to come through the Regional
natical Olympiads which are generally con-
around October. Further information may be
ɪd from: The National Board for Higher Math-
;, DAE, Anushakti Bhavan, C S M Marg, Bombay
9.

**Sample Problems from IMO**

- *(IMO 92, Problem 2)* Let **R** denote the set of all real numbers. Find all functions $f$: **R**—>**R** such that for all $x,y$ in **R**

$$f(x^2 + f(y)) = y + (f(x))^2$$

- *IMO 95, Problem 6)* Let $p$ be an odd prime number. Find the number of subsets $A$ of the set $\{1,2...,2p\}$ such that i) $A$ has exactly $p$ elements, and ii) the sum of all the elements in $A$ is divisible by $p$.

begun (*). The aims of the IMO are:

- to discover, encourage and challenge mathematically gifted young people in all countries;
- to foster friendly relations between mathematicians of all countries;
- to create an opportunity for the exchange of information on school syllabi and practice throughout the world.

The IMO consists of a written contest held on two consecutive days. Each day the contestants have to solve three problems in four-

and-a-half hours. The problems are all from high school mathematics (no calculus). They are of an elementary nature but rather difficult and their solutions require a certain degree of insight and creativity.

India has been participating in the IMO since 1989 and has so far bagged 1 gold, 15 silver and 20 bronze medals. The NBHM awards scholarships to the Olympiad participants if they wish to pursue mathematics and also conducts Nurture Programmes for them every year at leading institutes in the country.

**C R Pranesachar, DAE, Department of Mathematics, Indian Institute of Science, Bangalore.**

# 1994 Fields Medals

The most prestigious award for mathematics is the Fields Medal which is awarded once in four years to three or four young mathematicians for their outstanding contributions. They receive the Medal during the International Congress of Mathematicians held once in four years.

In the last International Congress of Mathematicians held in Zurich, Switzerland in August 1994 the following four mathematicians were awarded the Fields Medal: *Jean Bourgain,* Institute for Advanced Study, Princeton, USA; *Pierre-Louis Lions,* University of Paris-Dauphine, Paris; *Jean-Christopher Yoccoz,* University of Paris-Sud, Paris; *Efim Isaakovich Zelmanov,* University of Wisconsin, USA.

# 1995 Nobel Prizes

**Physics**

The 1995 Nobel prize in Physics has been awarded to *Martin L Perl* of Stanford University, USA and *Frederick Reines* of the Department of Physics, University of California at Irvine, USA for pioneering experimental contributions to lepton physics. They discovered two remarkable subatomic particles.

Martin L Perl and his colleagues found, through a series of experiments in the 1970s, a lepton, called the 'tau' ($\tau$). The tau has properties similar to the electron, but is about 3500 times heavier. Their discovery of the tau was the first sign that a third 'family' of fundamental building blocks existed. (The second family has the muon ($\mu$) which is some 200 times heavier than the electron)

Frederick Reines and the late Clyde L Cowan, Jr., demonstrated experimentally in the 1950s, the existence of the antiparticle of the electron-neutrino $v_e$. This was a remarkable feat

because neutrinos and anti-neutrinos interact very weakly with matter and are thus extremely difficult to detect experimentally.

**Physiology or Medicine**

Research on malformation in the fruitfly fetched three developmental biologists: *Edward B Lewis* of the Department of Biology, California Institute of Technology, *Christianan Nusslein-Volhard* of Max Planck Institute for Development Biology, Tubingen and *Eric Wieschaus* of the Department of Molecular Biology, Princeton University the Nobel prize in Physiology or Medicine for the year 1995. Their work on the fruitfly *Drosophila melanogaster* helped uncover many secrets of embryonic development. They created mutations in the genes of the fly which could delete or duplicate entire body segments. This work has significantly advanced our knowledge of the genetic control of development.

**Chemistry**

The 1995 Nobel Prize in Chemistry has been awarded to: *Paul Crutzen*, Max-Plank-Institute for Chemistry, Mainz, Germany; *Mario Molina*, Department of Earth, Atmospheric and Planetary Sciences and Department of Chemistry, MIT, Cambridge, MA, USA, and *F Sherwood Rowland*, Department of Chemistry, University of California, Irvine, CA, USA for their work in atmospheric chemistry, particularly concerning the formation and decomposition of ozone.

**100th year of wireless communication ...** In 1895 Jagadish Chandra Bose gave a public lecture at Town Hall, Calcutta, in which he demonstrated for the first time wireless transmission of electromagnetic signals through solid walls; it quickly made him famous throughout Bengal. As a result of that growing fame, the government of Bengal sent him on a nine-month lecture tour of Europe, where in December 1896 he repeated his demonstrations of wireless transmission at the Royal Institution before an audience that included Lord Kelvin. That event anticipated by a year Guglielmo Marconi's more celebrated (and commercially exploited) wireless transmission demonstrations in the same city.

**Poisson's view ...** That the French mathematician Poisson (1781 - 1840) liked teaching can be seen from his own words: "Life is made beautiful by two things — studying mathematics and teaching it".

# Guidelines for Authors

***Resonance** - journal of science education* is primarily targeted to undergraduate students and teachers. The journal invites contributions in various branches of science and emphasizes a lucid style that will attract readers from diverse backgrounds. A helpful general rule is that at least the first one third of the article should be readily understood by a general audience.

Articles on topics in the undergraduate curriculum, especially those which students often consider difficult to understand, new classroom experiments, emerging techniques and ideas and innovative procedures for teaching specific concepts are particularly welcome. The submitted contributions should not have appeared elsewhere.

Manuscripts should be submitted in *duplicate* to any of the editors. Authors having access to a PC are encouraged to submit an ASCII version on a floppy diskette. If necessary the editors may edit the manuscript substantially in order to maintain uniformity of presentation and to enhance readability. Illustrations and other material if reproduced, must be properly credited; it is the author's responsibility to obtain permission of reproduction (copies of letters of permission should be sent). In case of difficulty, please contact the editors.

***Title*** Authors are encouraged to provide a 4-7 word title and a 4-10 word sub-title. One of these should be a precise technical description of the contents of the article, while the other must attract the general readers' attention.

***Author(s)*** The author's name and mailing address should be provided. A photograph and a brief (in less than 100 words) biographical sketch may be added. Inclusion of phone and fax numbers and e-mail address would help in expediting the processing of manuscripts.

***Summary and Brief*** Provide a 2 to 4 sentence summary, and preferably a one sentence brief for the contents page.

***Style and Contents*** Use simple English. Keep the sentences short. Break up the text into logical units, with readily understandable headings for each. Do not use multiple sub sections. Articles should generally be 1000-2000 words long.

***Illustrations*** Use figures, charts and schemes liberally. A few colour illustrations may be useful. Try to use good quality computer generated images, with neatly labelled axes, clear labels, fonts and shades. Figure captions must be written with care and in some detail. Key features of the illustration may be pointed out in the caption.

***Boxes*** Highlights, summaries, biographical and historical notes and margin notes presented at a level different from the main body of the text and which nevertheless enhance the interest of the main theme can be placed as boxed items. These would be printed in a different typeface. Such a boxed item should fit in a printed page and not exceed 250 words.

***Suggested Reading*** Avoid technical references. If some citations are necessary, mention these as part of the text. A list of suggested readings may be included at the end.

***Layout*** It is preferable to place all the boxes, illustrations and their captions after the main text of the article. The suggested location of the boxes and figures in the printed version may be marked in the text. In the printed version, the main text will occupy two-thirds of each page. The remaining large margin space will be used to highlight the contents of key paragraphs, for figure captions, or perhaps even for small figures. The space is to be used imaginatively to draw attention to the article. Although the editors will attempt to prepare these entries, authors are encouraged to make suitable suggestions and provide them as an annexure.

***Book Reviews***

The following types of books will be reviewed : (1) text books in subjects of interest to the journal; (2) general books in science brought to the attention of students/teachers; (3) well-known classics; (4) books on educational methods. Books reviewed should generally be affordable to students/teachers (price range Rs.50 to 300).

New books will get preference in review. A list of books received by the academy office will be circulated among the editors who will then decide which ones are to be listed and which to be reviewed.

# Acknowledgements

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*Pierre-Simon de Fermat (1601-1665) is acknowledged to be the founder of modern number theory. This achievement overshadowed his independent invention of analytical geometry and his method of drawing tangents — which was a long step towards differential calculus. He is also the discoverer of the principle of least time in optics, the earliest example of a minimum principle in physics.*

*A lawyer by profession, Fermat pursued mathematics as a hobby. Much of his mathematics was written in the margins of books and letters. So when it came to knotty problems, Fermat frequently complained that he "wanteth roome" and failed to complete his proofs. This failing has been a plague to mathematicians ever since.*

Pierre-Simon de Fermat

1601-1665

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